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A COMPUTER PROGRAM FOR THREE-DIMENSIONAL LIFTING BODIES IN SUBCONIC INVISCID FLOW

F. A. Woodward, et al

Flow Research, Incorporated

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A computer program for the analysis of wing-body combinations in subsonic flow is described. The configuration is represented by a large number of surface panels, each containing a constant source distribution. The circulation about lifting surfaces is provided by a system of vortex lattices located on the mean camber surface. The strengths of the sources and vortices which satisfy the boundary condition of tangential flow for a given Mach number, angle of attack, and/or angle of yaw are determined by

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solving a system of linear equations by an iterative procedure.

The program computes the pressure coefficients at the panel centroids and integrates these pressures numerically to obtain the lift, drag, and pitching moments of the configuration.

PREFACE

This program was sponsored by the Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, and was monitored by Mr. James Gillespie. This program was authorized by Contract DAAJ02-73-C-0065, DA Task 1F162204AA4102.

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INTRODUCTION

The computer program is based on a program developed by Drs. Walter Krauss and Peter Sacher at Messerschmidt-Boelkow-Blohm in Munich, Germany, and reported in Reference 1. The MBB Program uses a method developed by Dr. Paul Rubbert and Gary Saaris at the Boeing Company, Reference 2, which in turn stems from the well-known Douglas Neumann Program originated by John Hess and A. M. O. Smith, Reference 3.

A listing of the MBB Program was provided by Dr. Wolfgang Schmidt of the Dornier Company. The present computer program retains the basic structure of the MBB Program, but has been extended to include a plotting package, analysis of yawed configurations, and many other features useful in the analysis of bluff bodies in subsonic flow.

AERODYNAMIC THEORY

DESCRIPTION OF METHOD

The configuration surface is divided into a large number of panels, each of which contains a constant source distribution. In addition, an internal vortex lattice is located along the mean chord of lifting surfaces to provide circulation to the flow. A typical configuration panel subdivision is shown in Figure 1.

Analytical expressions for the perturbation velocity field induced by a constant source distribution on an arbitrary quadrilateral panel are given by Hess and Smith (Reference 3). Similarly, the velocity field induced by the elements of a vortex lattice are given by Rubbert and Saaris (Reference 2). The perturbation velocities are used to calculate the coefficients of a system of linear equations relating the magnitude of the normal velocities at the panel control points to the unknown source and vortex strengths. The source and vortex strengths which satisfy the boundary condition of tangential flow at the control points for a given Mach number and angle of attack are determined by solving this system of equations by an iterative procedure. The pressure coefficients at panel control points are then calculated in terms of the perturbation velocity components, and the forces and moments acting on the configuration obtained by numerical integration.

The perturbation velocity components induced by the sources and vortices are described in the following paragraphs, together with the formation and solution of the boundary condition equations, and the procedure used to calculate the pressure coefficients, forces and moments on the configuration.

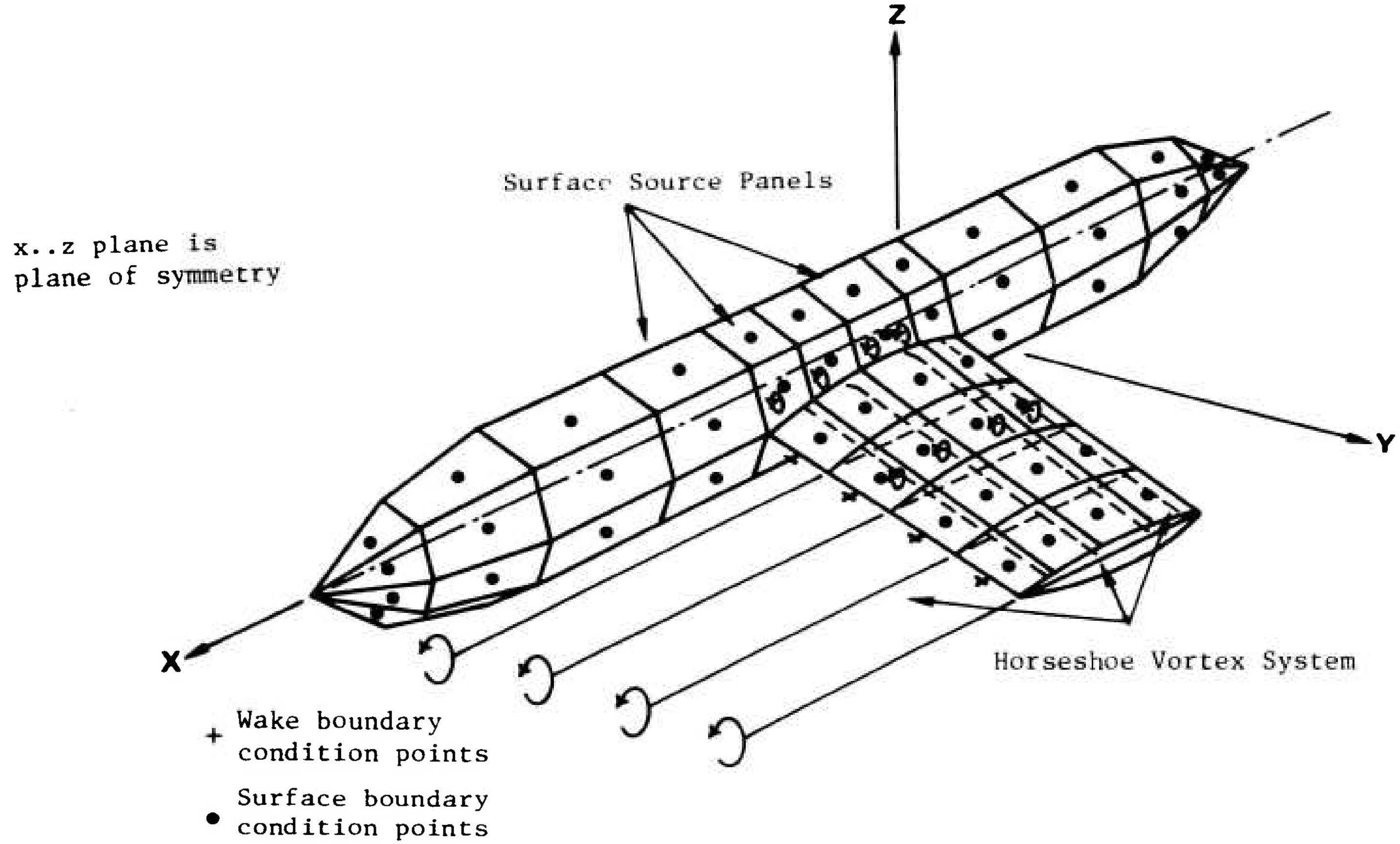


Figure 1. **Source and Vortex Panel Arrangement on Wing-Body Combination.**

THE INCOMPRESSIBLE VELOCITY COMPONENTS

The perturbation velocity components u, v, and w induced by a constant distribution of sources on an arbitrary quadrilateral panel are derived in Reference 3, so only the final expressions will be reported here. Consider the panel shown in Figure 2.

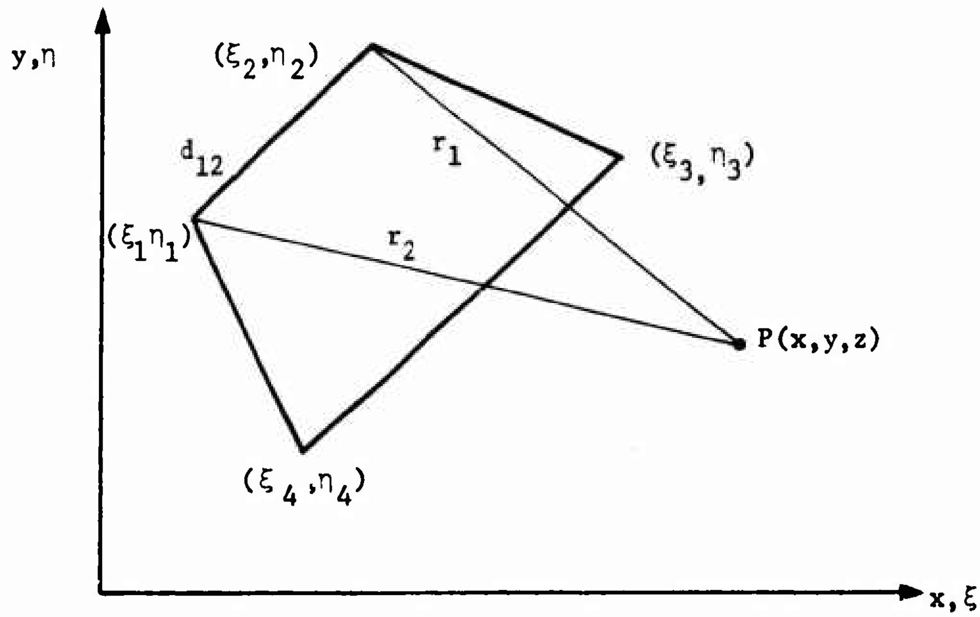


Figure 2. Source Panel Geometry.

The panel is assumed to lie in the plane z = 0, and the corners are numbered clockwise for reference. The perturbation velocities of point P(x,y,z) are given as the sum of the contributions of the four sides of the quadrilateral as follows:

$$u = -H_{12}Q_{12} \quad -H_{23}Q_{23} \quad -H_{34}Q_{34} \quad -H_{41}Q_{41} \tag{1}$$

$$v = K_{12}Q_{12} \quad +K_{23}Q_{23} \quad +K_{34}Q_{34} \quad +K_{41}Q_{41} \tag{2}$$

$$w = \frac{|z|}{z} \left[\Delta\theta - J_{12} \quad -J_{23} \quad -J_{34} \quad -J_{41} \right] \tag{3}$$

where

$$K_{ij} = \frac{\xi_j - \xi_i}{d_{ij}}$$

$$H_{ij} = \frac{\eta_j - \eta_i}{d_{ij}}$$

$$Q_{ij} = \log \frac{r_i + r_j + d_{ij}}{r_i + r_j - d_{ij}}$$

$$J_{ij} = \frac{|D_{ij}|}{D_{ij}} \left[\tan^{-1} \left(\left|\frac{z}{D_{ij}}\right| \frac{T_{ij}}{r_i} \right) - \tan^{-1} \left(\left|\frac{z}{D_{ij}}\right| \frac{P_{ij}}{r_i} \right) \right]$$

$$D_{ij} = (x - \xi_i) H_{ij} - (y - \eta_i) K_{ij}$$

$$P_{ij} = (\xi_i - x) K_{ij} + (\eta_i - y) H_{ij}$$

$$T_{ij} = (\xi_j - x) K_{ij} + (\eta_j - y) H_{ij}$$

$$r_i = [(x - \xi_i)^2 + (y - \eta_i)^2 + z^2]^{1/2}$$

$$d_{ij} = [(\xi_i - \xi_j)^2 + (\eta_i - \eta_j)^2]^{1/2}$$

and $\Delta\theta = 2\pi$ if the point P lies inside the boundary in the plane of the panel; $\Delta\theta = 0$ otherwise.

For the points located more than four times the length of the major diagonal from the panel centroid, the quadrilateral is approximated by a point source at the centroid. This simplifies the expression for the

velocity components considerably.

In this case,

$$u = (x - \bar{x})\ S/\bar{r}^3 \tag{4}$$

$$v = (y - \bar{y})\ S/\bar{r}^3 \tag{5}$$

$$w = (z - \bar{z})\ S/\bar{r}^3 \tag{6}$$

where

$$\bar{r} = [(x - \bar{x})^2 + (y - \bar{y})^2 + (z - \bar{z})^2]^{1/2}$$

S = panel area

and $\bar{x}$, $\bar{y}$, $\bar{z}$ are the coordinates of the panel centroid.

Additional multipole expansion formulas for the velocity components given in Reference 3 are not used in this program.

The perturbation velocity components induced by a line vortex are derived in Reference 2. The line vortex is represented by a vector $\vec{L}$ as shown in Figure 3 below. It induces a counterclockwise circulation in a plane perpendicular to $\vec{L}$ if the vortex strength is positive.

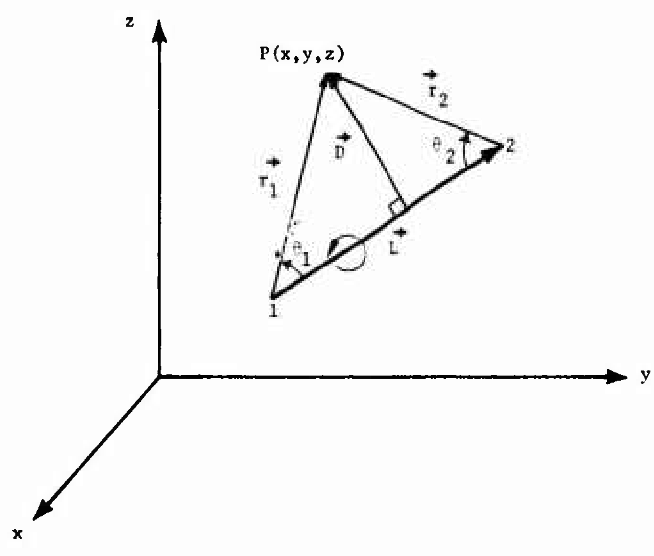


Figure 3. Line Vortex Geometry.

The velocity at P(x, y, z,) is perpendicular to the plane containing $\vec{L}$ and the point P, and is given by Biot-Savart's Law as

$$V_1 = \frac{\gamma}{4\pi} \int_1^2 \frac{\vec{D} \times \vec{L}}{|\vec{D} \times \vec{L}|} \frac{\sin\theta}{D^2} ds$$

$$= \frac{\gamma L}{4\pi} \frac{\vec{L}\times\vec{r}}{(\vec{L} \times \vec{r}_1)^2} (\cos\theta_1 - \cos\theta_2) \qquad (7)$$

A quadrilateral vortex is composed of four vortex segments of equal strength. The velocity induced by a quadrilateral vortex is

$$\vec{V} = u.\vec{i} + v.\vec{j} + w.\vec{k} = \sum_{n=1}^{4} \vec{V}_n \qquad (8)$$

where $\vec{V}_n$ is the velocity induced by segment n, and u, v, and w are the perturbation velocity components.

A vortex lattice consists of a series of quadrilateral vortices of varying strengths, with adjacent edges superimposed. The vortex wake is approximated by giving the last vortex quadrilateral a large but finite length. The net strength of the trailing vortices in the wake is the sum of the strengths of the individual elements in the lattice, as indicated in Figure 4.

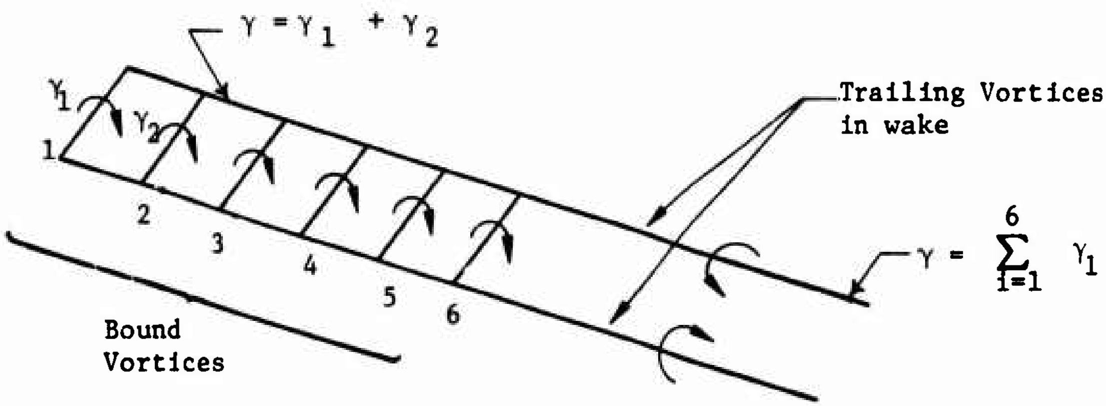


Figure 4. Vortex Lattice

The relative strengths of the individual bound vortices in the lattice are specified in advance. The circulation around each airfoil section is determined by the net strength of each vortex lattice.

COMPRESSIBILITY CORRECTIONS

The velocity components in compressible flow are found by applying Gothert's Rule (Reference 4). Two options are available in the program for applying the compressibility corrections, and are designated Rule 1 and Rule 2.

Rule 1 applies the method originally proposed by Gothert. The incompressible velocity components are calculated on an analogous body obtained by the following transformation:

$$x_a = x$$
$$y_a = By \qquad (9)$$
$$z_a = Bz$$

where

$$B = \sqrt{1-M^2}$$

The boundary conditions of tangential flow are applied on the analogous body, and the resulting incompressible perturbation velocities are transformed back to the real body by

$$u = u_a / B^2$$
$$v = v_a / B \qquad (10)$$
$$w = w_a / B$$

The total velocity vector at a given point is then

$$U = U_\infty \cos\alpha \cos\beta + u$$
$$V = U_\infty \sin\beta + v \qquad (11)$$
$$W = U_\infty \sin\alpha \cos\beta + w$$

It is now known that this compressibility rule yields good results only for slender bodies at small angles of attack. The validity of this rule decreases with increasing values of the surface slope. This

effect is particularly noticeable for two-dimensional airfoil sections. In the vicinity of the nose, Gothert's Rule (which is equivalent to the Prandtl-Glauert Rule in this example) gives excessively high suction peaks on the upper surface. The reason for this failure of the theory is the manner in which the boundary conditions are satisfied. Since the boundary conditions are satisfied at the surface of the analogous body which is thinner by the factor B than the real body, the curvature of the flow near the nose is correspondingly increased, resulting in higher suction peaks. In order to eliminate this effect, it is necessary to satisfy the boundary conditions on the surface of the real body.

Rule 2 was first proposed by Kraus in Reference 1. Beginning with the analog body as before, the expressions for the perturbation velocity components are corrected for compressibility, using Equation 10, prior to solving the boundary condition equations. The boundary conditions of tangential flow are then applied on the surface of the real body, resulting in improved results for the velocities and pressure coefficients.

THE BOUNDARY CONDITION EQUATIONS

The boundary condition of tangential flow at panel control points establishes a system of linear equations for determining the strengths of the source and vortex distributions. The geometrical relationship between each panel and control point is required to evaluate the coefficients of this system of equations.

Panel Geometry

A typical panel subdivision of a wing-body configuration is illustrated in Figure 1. A reference coordinate system is established with origin at or near the nose of the configuration, having an x-axis lying in the plane of symmetry parallel to the body axis, and a vertical z axis. Symmetry of the body about the x, z plane is not required. However, if the body is symmetric, only those panels located on the positive y side of the x, z plane are required.

The body panel corners are defined by the intersections of a series of planes normal to the x axis, and longitudinal meridian lines. A maximum of 70 body sections may be used, and each section may contain up to 60 points around the half-circumference. The body panel corner points may be shifted longitudinally to aid in paneling wing-body intersections. The body panels are numbered in sequence from the top to the bottom of each circumferential ring, starting from the most forward ring.

The wing panels are defined by the intersections of a series of vertical planes parallel to the plane of symmetry, and lines of constant percent chord. A maximum of 40 wing sections may be defined, each containing up to 60 airfoil ordinates. The same number of ordinates are required on the upper and lower surfaces of the airfoil, at approximately the same percent chord locations, in order to properly define the internal vortex panels.

The wing panel corner points may be shifted laterally to aid in paneling wing-body intersections. The wing panels are numbered sequentially, and follow the body panels. Beginning with the inner chordwise strip of panels, the numbering starts at the trailing edge of the lower surface, and ends at the trailing edge of the upper surface. A maximum of 1500 panels may be used to define the external surfaces of the wing and body. If the configuration is symmetric, this implies a maximum of 750 panels on one side of the x, z plane.

Vortex lattice panels are automatically defined on the mean chord plane of the wing. The panel corner points are obtained by averaging the upper and lower surface airfoil ordinates at each percent chord location. One additional vortex panel is defined in the wake aft of the trailing edge of each chordwise strip of wing panels to provide control points for satisfying the Kutta condition. The additional panel lies in the plane of the trailing edge bisector. For wing-body combinations, additional vortex lattices are required inside the body to provide a mechanism for carry-over of lift. A maximum of 35 vortex lattices may be defined, and these are numbered subsequently following the wing panels.

The four input points defining a panel do not necessarily lie in the same plane. The technique used to approximate the panel by an equivalent planar panel was developed by Hess and Smith, Reference 5, and is summarized in Appendix I. Using this method, a panel coordinate system is defined with origin at the panel centroid and lying in the mean plane of the input points. The x axis of the panel coordinate system is parallel to one diagonal, the z axis is normal to the plane of the panel, and the y axis is perpendicular to the other two. Since the velocity components induced by the source distributions are given in terms of the panel coordinate system, a nine element transformation matrix T_{ij} is calculated for each panel to transform the coordinates of points and the components of vectors from the reference coordinate system to the panel coordinate system. In addition, the panel area, the coordinates of the centroid, and the length of the principal diagonal are calculated.

Normal Velocity at Panel Control Points

Each surface panel is assigned a control point located at the panel centroid. Each vortex lattice is assigned a control point just behind the trailing edge of the wing in the plane of the trailing edge bisector. (This point is normally located 1 percent of the local chord behind the trailing edge.)

The resultant velocity normal to panel i at its control point is the sum of the normal component of the free-stream velocity vector and the normal velocities induced by the panel source and vortex distributions. Setting the magnitude of the free-stream velocity vector equal to unity, its component normal to panel i is

$$R_i = \cos\alpha \cdot \cos\beta \cdot n_{x_i} + \sin\beta \cdot ny_i + \sin\alpha \cdot \cos\beta \cdot n_{z_i} \tag{12}$$

where n_{x_i}, n_{y_i}, and n_{z_i} are the direction cosines of the normal of panel i (see Appendix I), α is the angle of attack and β is the angle of yaw of the free-stream velocity vector in the reference axis system.

The normal component of velocity induced at the control point of panel i by the source and vortex distributions is given by

$$A_i = \sum_{j=1}^{N} (n_{x_i} \cdot v_{x_{ij}} + n_{y_i} \cdot v_{y_{ij}} + n_{z_i} \cdot v_{z_{ij}}) \, \sigma_j \tag{13}$$

where $v_{x_{ij}}$, $v_{y_{ij}}$, and $v_{z_{ij}}$ are the three components of velocity parallel to the reference axis at control point i induced by a unit strength source or vortex distribution on panel j and σ_j is the strength of the j^{th} singularity.

The three components of velocity parallel to the reference axes are obtained by multiplying the velocity components given by Equations (4), (5), and (6) in the panel coordinate system by the transformation matrix given in Appendix I. For example,

$$\begin{aligned} v_{x_{ij}} &= u_{ij}\, t_{1x_{ij}} + v_{ij}\, t_{1y_{ij}} + w_{ij}\, t_{1z_{ij}} \\ v_{y_{ij}} &= u_{ij}\, t_{2x_{ij}} + v_{ij}\, t_{2y_{ij}} + w_{ij}\, t_{2z_{ij}} \\ v_{z_{ij}} &= u_{ij}\, n_{x_{ij}} + v_{ij}\, n_{y_{ij}} + w_{ij}\, n_{z_{ij}} \end{aligned} \tag{14}$$

Combining Equations (12) and (13),

$$V_{n_i} = R_i + A_i$$

$$= R_i + \sum_{j=i}^{N} a_{ij}\,\sigma_j \tag{15}$$

where the aerodynamic influence coefficient a_{ij} is given by Equation(13).

Solution of the Boundary Condition Equations

The boundary condition of tangential flow at panel control points is satisfied if the normal velocities are set equal to zero on all panels.

Thus

$$\sum_{i=1}^{N} V_{ni} = 0$$

or

$$\sum_{i=1}^{N} \sum_{j=1}^{N} a_{ij}\,\sigma_j = -\sum_{j=1}^{N} R_i \tag{16}$$

In matrix notation,

$$[A_{ij}]\ \{\sigma_j\} = -\{R_i\} \tag{17}$$

where A_{ij} is the matrix of aerodynamic influence coefficients, and the right side of the equation is given by Equation (12).

This system of equations can be solved by direct inversion to determine the unknown source and vortex strengths. However, for the large order matrices usually encountered in aerodynamic problems, an iterative solution procedure is given in Reference 3. A modified Gauss-Siedel iteration procedure is employed in this computer program.

This matrix is subdivided into four partitions as follows:

$$A = \left[\begin{array}{c|c} A_{ss} & A_{vs} \\ \hline A_{sv} & A_{vv} \end{array}\right]$$

where A_{ss} is the matrix giving the influence of the source panels on the surface control points.

A_{sv} is the matrix giving the influence of the source panels on the vortex lattice control points.

A_{vs} is the matrix giving the influence of the vortex lattices on the surface control points, and

A_{vv} is the matrix giving the influence of the vortex lattices on the vortex lattice control points.

Equation (17) may now be written as

$$\begin{matrix} A_{ss} & A_{vs} \\ A_{sv} & A_{vv} \end{matrix} \cdot \begin{matrix} s_i \\ \gamma_i \end{matrix} = - \begin{matrix} R_{si} \\ R_{vi} \end{matrix} \qquad (18)$$

or

$$A_{ss}s_i + A_{vs}\gamma_i = - R_{si} \qquad (19)$$

$$A_{sv}s_i + A_{vv}\gamma_i = - R_{v_i} \qquad (20)$$

where s_i are the unknown source strengths, and γ_i are the unknown vortex strengths, A_{ss} is a square matrix of order NS, and A_{vv} is a square matrix of order NL, where NL is generally much smaller than NS.

The first step in each of the iteration cycles is to use Equation (19) only. The values for γ_i are taken from the previous cycle (or set equal to zero on the first cycle) and a solution for the array $\{s_i\}$ is obtained by the Gauss-Seidel procedure. These values for s_i are then used in Equation (20) to obtain γ_i by direct inversion:

$$\gamma_i = -A_{vv}^{-1} \left[R_{v_i} + \sum_{j=1}^{NS} A_{sv_{ij}} s_j \right] \tag{21}$$

These values are now used in the first step of the next cycle, and the procedure continues until convergence is achieved. The criterion for convergence is

$$\left| \sum_{i=1}^{NS} \left(\sum_{j=1}^{NS} A_{ss_{ij}} s_j + \sum_{j=1}^{NL} A_{vs_{ij}} \gamma_j + R_{s_i} \right) \right| \leq \varepsilon \tag{22}$$

where ε is some small number specified by the user. Normally $\varepsilon \leq 10^{-3}$.

More elaborate iteration schemes using smaller partitions of the A_{ss} matrix are described in Reference 6, but have not been incorporated into the present program.

CALCULATION OF THE PRESSURES, FORCES, AND MOMENTS

Once the source and vortex strengths have been determined, the three components of velocity at control point i may be obtained.

$$u_i = \cos\alpha \cos\beta + \sum_{j=1}^{N} v_{x_{ij}} \sigma_j \tag{23}$$

$$v_i = \sin\beta + \sum_{j=1}^{N} v_{y_{ij}} \sigma_j \tag{24}$$

$$w_i = \sin\alpha\cos\beta + \sum_{j=1}^{N} v_{z_{ij}}\,\sigma_j \qquad (25)$$

where the σ_j includes both source and vortex strengths, and $v_{x_{ij}}$, $v_{y_{ij}}$, and $v_{z_{ij}}$ are defined following Equation (13). The pressure coefficient is calculated using the exact isentropic formula

$$C_{P_i} = -\frac{2}{\kappa M^2}\left\{\left[1 + \frac{\kappa-1}{2}\,M^2\,(1-q_i^2)\right]^{3.5} - 1\right\} \qquad (26)$$

where

$$q_i^2 = u_i^2 + v_i^2 + w_i^2$$

For $M < .1$, the program uses the simpler formula

$$C_{P_i} = 1 - q_i^2 \qquad (27)$$

The forces and moments acting on the configuration can now be obtained by numerical integration. The normal force, side force, axial force, and pitching moments (about the origin of coordinates) of panel i are given by

$$X_i = S_i\,C_{P_i}\,n_{x_i} \qquad (28)$$

$$Y_i = S_i\,C_{P_i}\,n_{y_i} \qquad (29)$$

$$Z_i = S_i\,C_{P_i}\,n_{z_i} \qquad (30)$$

$$M_{x_i} = Z_i y_i - Y_i z_i \qquad (31)$$

$$M_{y_i} = X_i z_i - Z_i x_i \qquad (32)$$

$$M_{z_i} = Y_i x_i - X_i y_i \qquad (33)$$

where S_i is the area of the panel, n_{x_i}, n_{y_i}, and n_{y_i} are the direction cosines of the normal, and x_i, y_i and z_i are the coördinates of the panel control point.

The total force and moment coefficients are obtained by summing the panel forces and moments on both sides of the plane of symmetry

$$C_Z = \frac{1}{S_w} \sum_{i=1}^{N} Z_i \tag{34}$$

$$C_Y = \frac{1}{S_w} \sum_{i=1}^{N} Y_i \tag{35}$$

$$C_X = \frac{1}{S_w} \sum_{i=1}^{N} X_i \tag{36}$$

$$C_{M_z} = \frac{1}{S_w \bar{c}} \sum_{i=1}^{N} M_{z_i} \tag{37}$$

$$C_{M_y} = \frac{1}{S_w \bar{c}} \sum_{i=1}^{N} M_{y_i} \tag{38}$$

$$C_{M_x} = \frac{1}{S_w \bar{c}} \sum_{i=1}^{N} M_{x_i} \tag{39}$$

Finally, the lift, side force, and drag coefficients are

$$C_L = C_Z \cos\alpha - (C_X \cos\beta - C_Y \sin\beta) \sin\alpha \tag{40}$$

$$C_S = C_Y \cos\beta + C_X \sin\beta \tag{41}$$

$$C_D = (C_X \cos\beta - C_Y \sin\beta) \cos\alpha + C_Z \sin\alpha \tag{42}$$

The program computes the forces and moments acting on the body and the wing, and sums them to obtain the total forces and moments of the configuration. In addition, wing section forces and moments may be calculated at the user's option.

SEPARATED FLOW MODEL

The flow external to the boundary layer and the separated wake is essentially potential flow. To obtain a mathematical model with potential flow everywhere, the boundary layer and separated wake in the real case are replaced by fluid originating from the body surface as shown in Figure 5. Rules for the distribution of surface normal velocity to account for boundary layer growth upstream of separation have been formulated, and their use requires matching the boundary layer and the potential flow solution by iteration. Rules for distributing surface normal velocity in the separated region to obtain fluid which will displace the potential flow originating from upstream in the same way as the separated wake in the real case have not been formulated. However, for very unstreamlined bodies, a plausible approach is to make the surface normal velocity equal to the free-stream velocity component normal to the surface:

$$\vec{V}_s \cdot \vec{n} = \vec{V}_\infty \cdot \vec{n} \tag{43}$$

$\vec{V}_s$ = surface velocity

$\vec{V}_\infty$ = free-stream velocity

$\vec{n}$ = unit surface normal

To calculate the location of separation requires a matching of the boundary layer and potential flow solutions similar to that used for the boundary layer growth, a formidible job. However, for an aft body shape with rapid closure or for bodies having sharp corners, making an intuitive estimate of the separation point is consistent with the use of Equation 43.

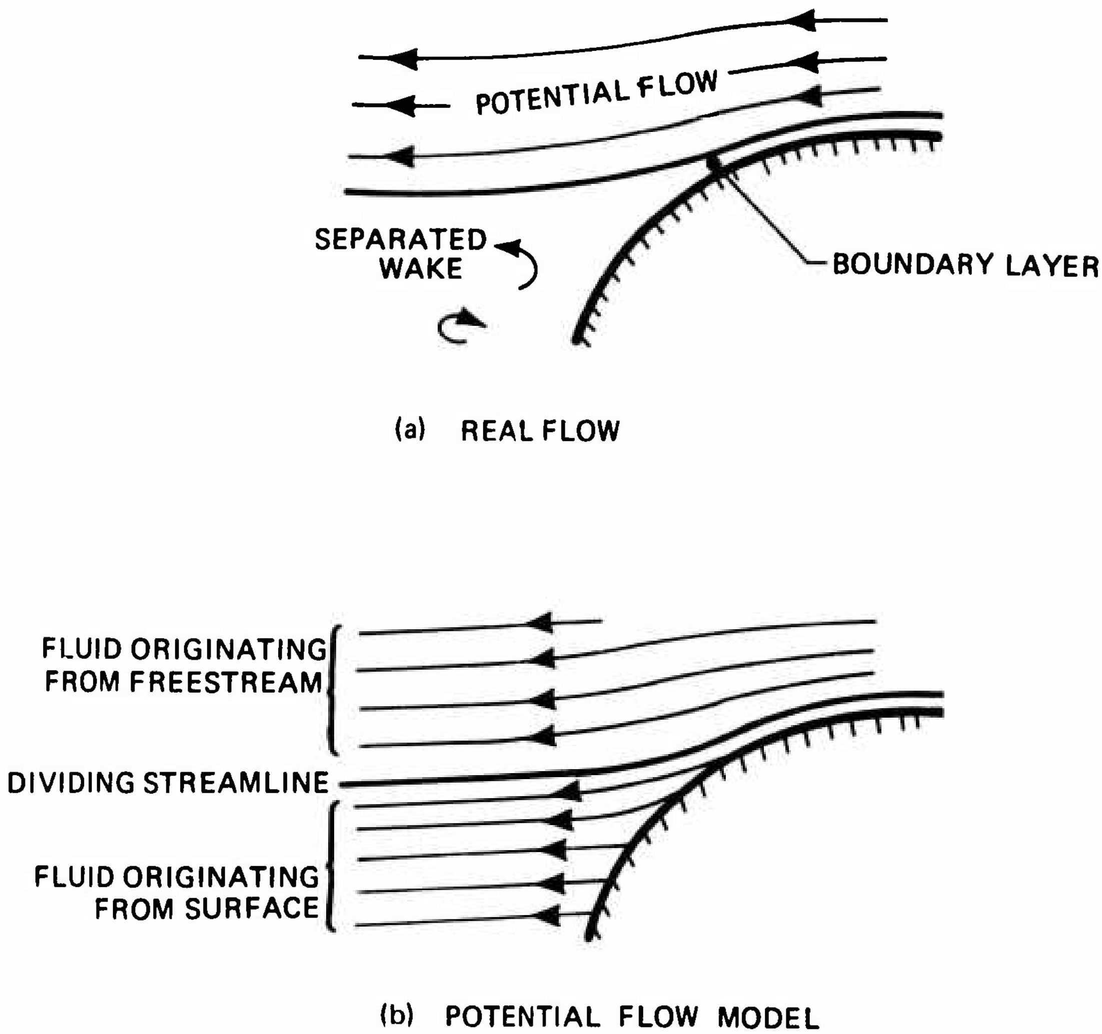


Figure 5. Modeling of Potential Flow to Account for Boundary Layer and Wake.

This approximate separation modeling was applied to the BO 105 helicopter fuselage configuration. Figure 6 shows the different choices used for the region where fluid was ejected according to Equation 43. The choice labeled Case A gave the best agreement with experiment upstream of separation as shown in Figures 7 and 8. The pressure distributions for Waterline 10 (see Figure 8) show that the ejection region was extended too far forward for Case B. The top centerline data (see Figure 7) shows that for Case B the ejection region was extended too high on the body. The presence of the boom and a milder closure evidently eliminates separation on the upper part of the body.

It should be noted that by proper choice of outflow distribution, the potential flow model shown in Figure 5b can make the flow external to the dividing streamline agree well with the real case and hence give the proper surface pressure upstream of separation, but it cannot be expected to simultaneously provide surface pressures that agree with the real flow in the separated region. The irrelevant result in this region is illustrated in Figure 8 beyond X = 39. An approximate replacement is to use the pressure at separation over the entire separated surface region. The experimental results shown in Figure 8 suggest this approach. This level can be estimated from the potential flow solution using boundary layer separation criteria. Applying a modified Townsend criterion to the Waterline 10 pressure distribution for separation modeling Case A gives the pressure level shown as C_{p_s} in Figure 8. This modified Townsend criterion, developed by F. A. Dvorak, is;

C_{p_s} = pressure coefficient at separation

$$= C_{f_o}\,(1-C_{p_o})\left\{-83.961 + 38.645\,\log\left[\frac{Re}{x_o}\,\frac{C_{f_o}^{3/2}}{C_p'}\,(1-C_{p_o})\right]\right\} + C_{p_o}$$

C_{p_o} = pressure coefficient at recovery

x_o = boundary layer development length to recovery point

C_p' = recovery pressure gradient

Re = Reynolds number based on length x_o

C_{f_o} = skin friction coefficient at recovery

$$= \frac{.074}{Re^{1/5}}$$

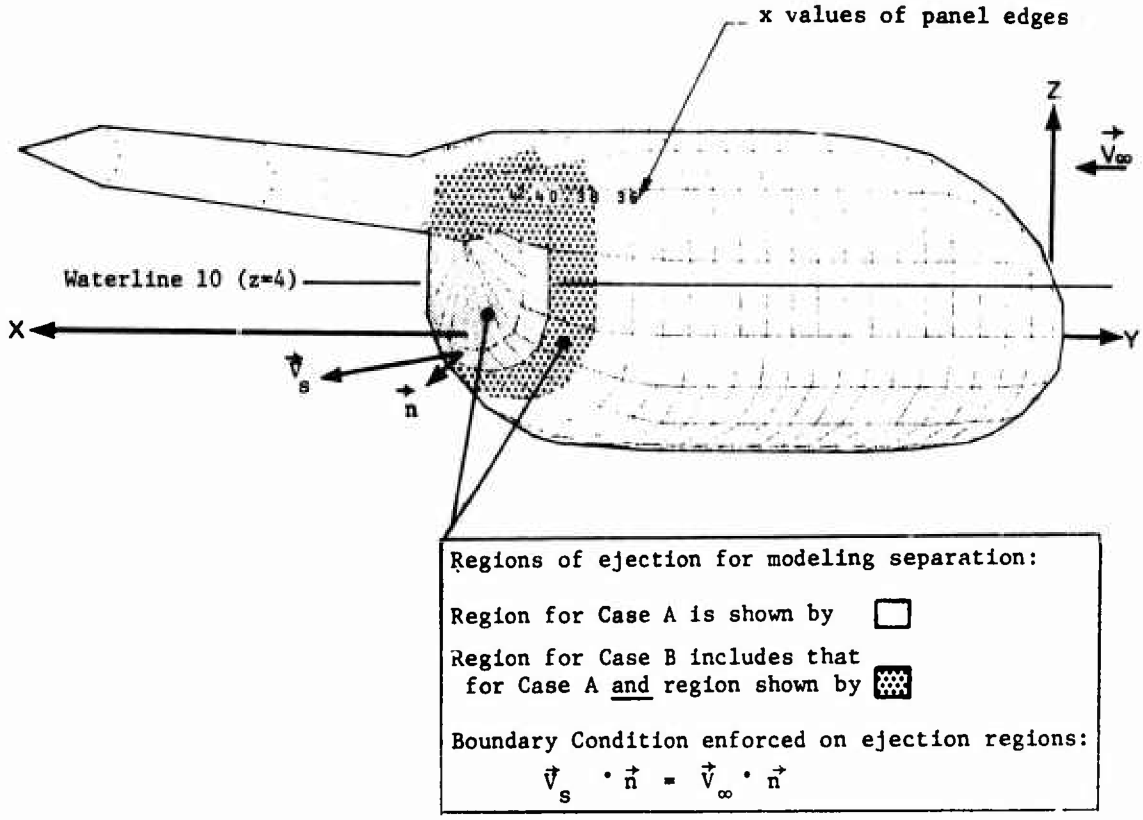


Figure 6. The BO 105 Helicopter Fuselage Showing Paneling and Separation Modeling.

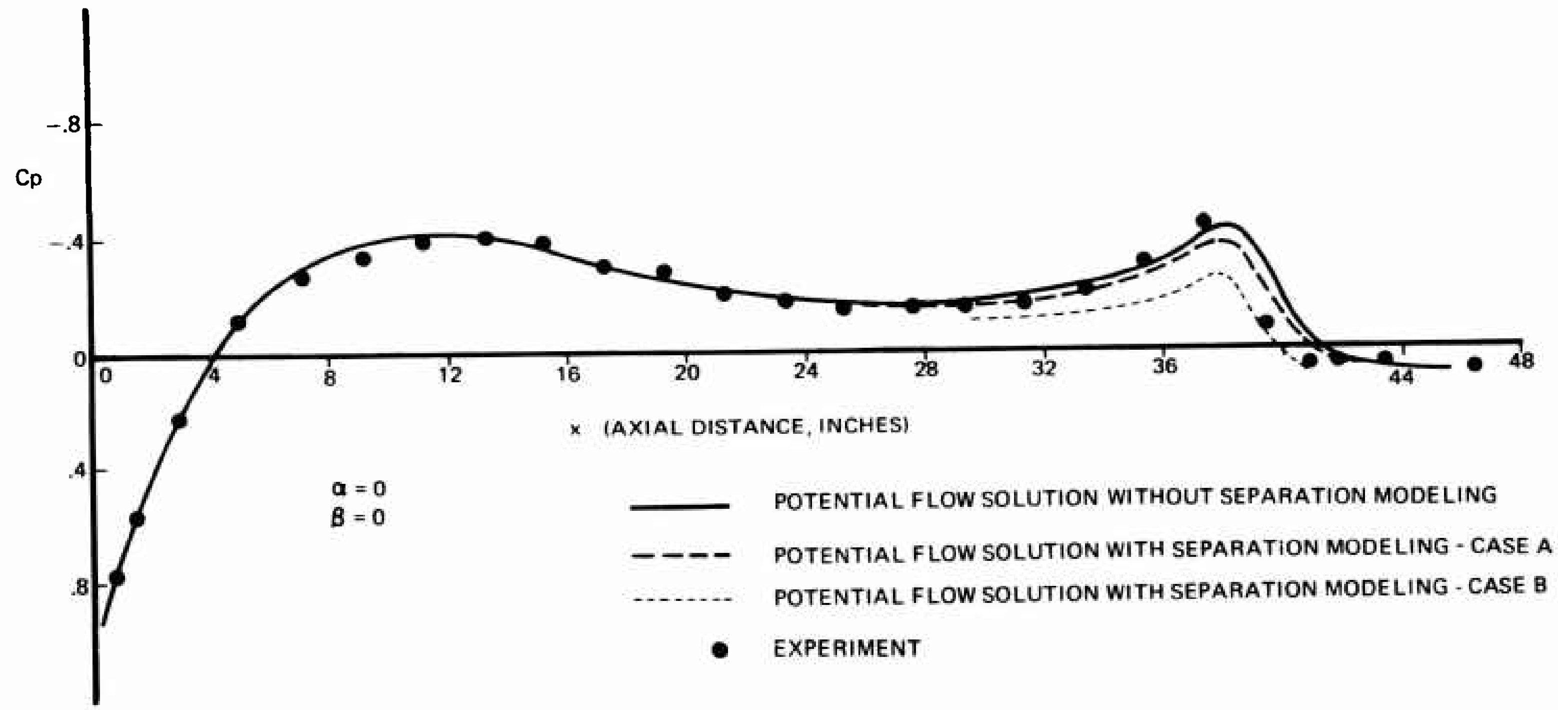


Figure 7. Pressure Distribution Along Top Centerline of the BO 105.

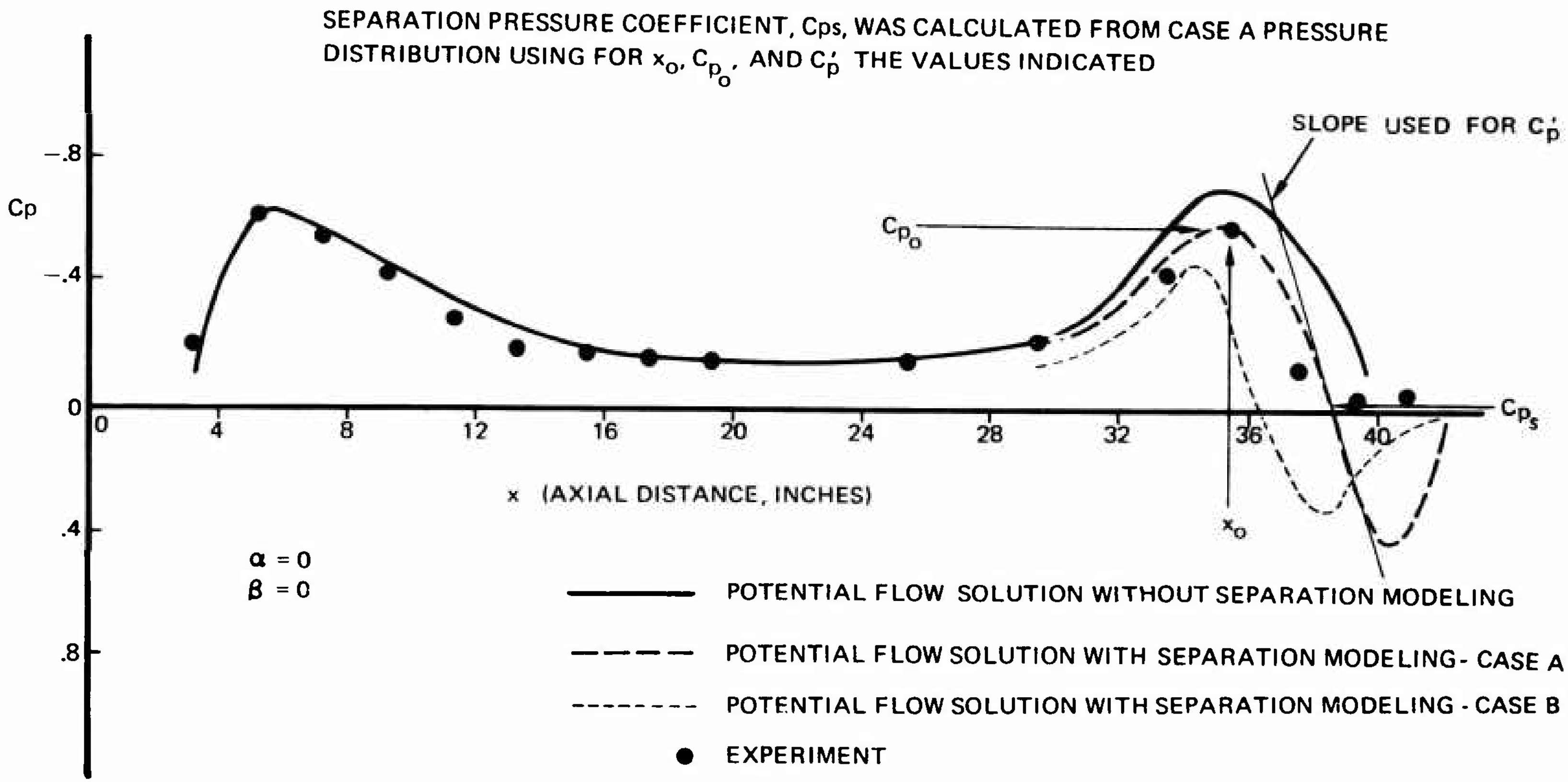


Figure 8. Pressure Distribution Along Waterline 10 of the BO 105.

The values for C_{p_o}, C'_p, and x_o that were taken from the Case A pressure distribution to calculate C_{p_s} are indicated in Figure 8. The boundary layer development length x_o was approximated by using the axial distance from the nose of the body to the recovery point. For the recovery pressure gradient C'_p, the maximum gradient in the recovery region was used.

For the cases shown in Figures 7 and 8, experimental results are available to determine the best ejection configuration for the paneling used, namely, Case A. An obvious problem is that in the absence of experimental data, it is not known where to start the surface ejection. It may be possible to determine this point by an iterative procedure using a boundary layer separation criterion. The idea is to start the surface ejection at the separation point calculated from the preceding cycle, an initial guess being used for the first cycle. The example in Figures 7 and 8 shows that for a jump start, ejection must begin some distance downstream from the calculated separation point. Clearly, the iterative procedure suggested requires a gradual initiation of ejection, and the shape used for this initiating "ramp" is critical for convergence and for obtaining an accurate modeling of separation as pictured in Figure 5. Also denser paneling than shown in Figure 6 is necessary to provide more resolution for the ejection distribution.

COMPUTER PROGRAM

PROGRAM DESCRIPTION

The program developed to calculate the pressure distribution and aerodynamic characteristics of wing-body combinations in subsonic flow is written in FORTRAN IV. A maximum of 1500 source panels and 35 vortex lattices may be used to represent the configuration. It is designed to operate on both the CDC 6600 or IBM 360/370 series of computer with minor modifications. The program requires approximately 210,000 (octal) words storage on the CDC computer, and operates in OVERLAY mode. The program requires five peripheral disc files in addition to the input and output files.

PROGRAM STRUCTURE

The overlay structure of the program is illustrated in Figure 9. The main overlay program is designated WBOLAY, and calls the three primary overlay programs WBPAN, WBPLOT, and WBAEOR. The complete program consists of 16 subroutines in addition to standard library and plot subroutines. Descriptions of these subroutines are contained in Appendix II of this report.

PROGRAM INPUT DATA

The input to the program is divided into three parts: the geometry input, the plot input, and the aerodynamic input. The input requirements of each part are described below. A sample input is given in Appendix III, and a sample output in Appendix IV.

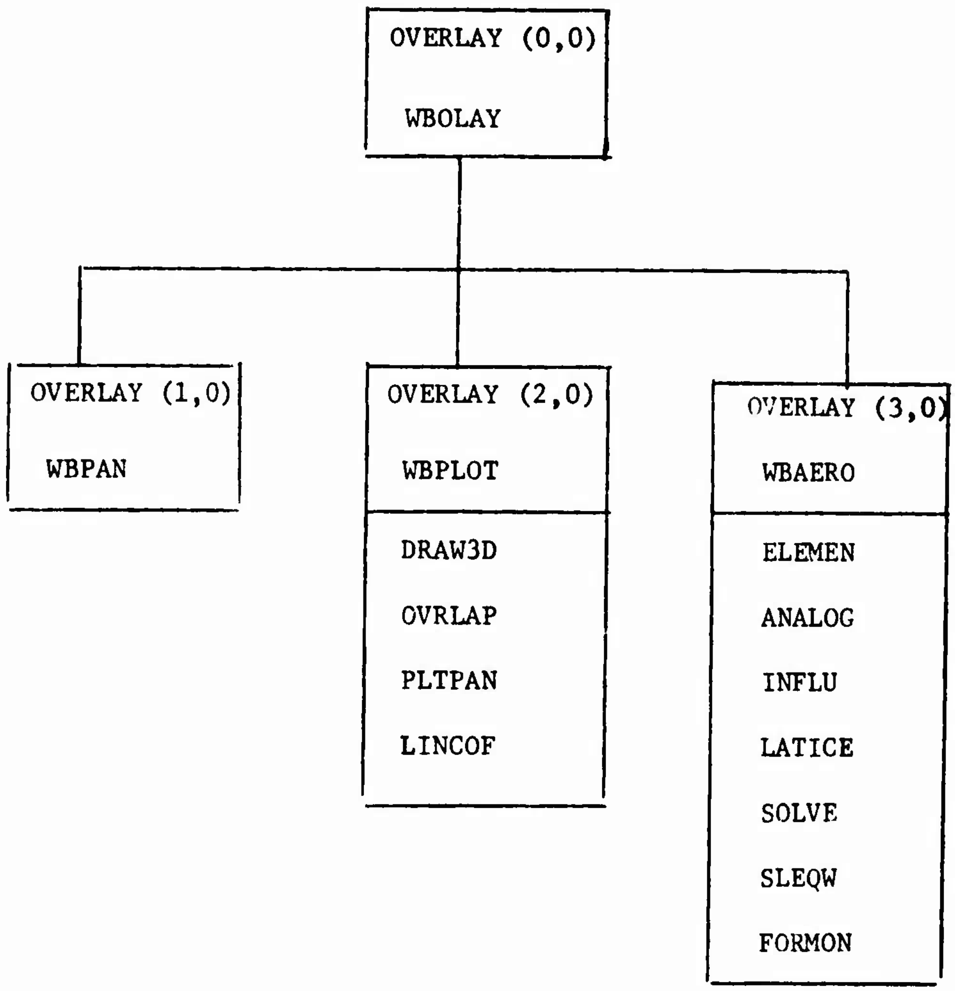


Figure 9. Program Overlay Structure.

Geometry Input Cards

If the configuration is symmetrical about the x, z plane, geometrical input is required for only one side of the configuration. The convention used herein is to present that half of the configuration lying on the positive y side of the x, z plane. If the configuration is not symmetric, complete geometrical input is required.

Card 1 - General Identification - Card 1 contains any desired identifying information in Columns 1-80.

Card 2 - Configuration Parameters -

Col.	Variable	Value	Description
10	CASE	1	Isolated body only
		2	Isolated wing only
		3	Wing-body combinations
20	PLOT	0	No plot output
		1	Plot output requested
30	SIM	0	Configuration symmetric about x, z plane; panel geometry required on one side only
		1	Configuration symmetric about x, z plane. Panel geometry input required on one side only; panel geometry output calculated for both sides. (Used when analyzing symmetric configuration in yaw.)
		-1	Unsymmetric configuration. Panel geometry input required for both sides
40	ISAVE	0	Geometry and influence coefficient matrices not saved
		1	Geometry and influence coefficient matrices saved in previous run to be used (TAPE 11 must be requested and card sets 3-8 omitted)
		-1	Geometry and influence coefficient matrices to be saved on TAPE 11

Col.	Variable	Value	Description
50	PRINT	0	Normal output - see Program Output Section (page 41)
		1	Optional output 1 - Includes panel geometry, coordinate transformation matrices, and panel forces and moments
		2	Optional output 2 - Panel velocity components and influence coefficients Requires large line count limit
		3	Optional output 3 - The aerodynamic influence coefficient matrix, the right side of the matrix equation, and all solution iterations
		4	Optional output 4 - This option prints out the successive solution iterations only

Note: The normal output is always printed in addition to any optional output selected.

Card Set 3 - Single Panel Input - This card set allows individual panels to be input by specifying the coordinates of the four corner points in clockwise order. Any number of panels may be input in this manner. It also allows individual panels to be deleted by specifying the panel indices. A maximum of 100 panels may be deleted.

Card 3A - Single Panel Control Card

Col.	Variable	Value	Description
1-10	SINGPA	0	No single panel input; omit card set 3B, continue reading input cards
		1	Corner point coordinates of this panel follow on card set 3B
11-20	NOPAN	Arbitrary Integer	Number of panels to be deleted. If non-zero, panel indices follow on card set 3C

Card 3B - Panel Corner Point Input

Col.	Variable	Value	Description
1-10	X(I)	Arbitrary (floating point)	x coordinate of corner I
11-20	Y(I)	"	y coordinate of corner I

Col.	Variable	Value	Description
21-30	Z(I)	Arbitrary (floating point)	z coordinate of corner I

Repeat card 3B four times, once for each corner of the panel.

Card Set 3C - Indices of Deleted Panels

NOPAN indices of deleted panels are read (7I10) format) if NOPAN > 0 on card 3A. A maximum of 100 panels may be deleted. Wing and body vortex lattice control panels may not be deleted.

Card Set 4 - Body Panel Input - This card set allows the body panels to be calculated automatically, from the section geometry data. Five options are available for inputting the section geometry. The XYZ program input referred to below conforms with the format of Reference 7. Omit this card set if CASE = 2 on card 2.

Card 4A - Number of Body Sections

Col.	Variable	Value	Description
1-10	NB	Arbitrary Integer	Number of body sections ($2 \leq NB \leq 70$)

Card 4B - Body Section Geometry

Col.	Variable	Value	Description
1-10	XBE	Arbitrary (floating point)	x coordinate of origin of body section coordinate system except blank when XYZ program input format is used
11-20	YBE	"	Similarly the y coordinate
21-30	ZBE	"	Similarly the z coordinate
31-40	MB	Arbitrary Integer	No. of input points on section ($3 \leq MB \leq 60$)
			If MB <0, XYZ program input format requested
50	OPT	0	Body section geometry input by y-z coordinates on card set 4C and 4D
		1	Body section geometry same as preceding body section - card set 4C or 4D omitted. Note: YBE and ZBE are additive to preceding values.

Card 4B - Body Section Geometry (cont'd)

Col.	Variable	Value	Description
		2	Body section geometry input in polar coordinates r, θ on card set 4C
		3	Body of revolution, section geometry input as section radius and theta increment on card set 4C
60	FLAG	0	Normal body section
		1	Terminal body section (end of current body panel network)

Card Set 4C - Body Section Coordinates (Normal Input)

Col.	Variable	Value	Description
1-10	B(J)	Arbitrary (floating point)	y coordinate of point J if OPT = 0, or, angular coordinate (in degrees) of J if OPT = 2 or, increment angle Δθ in degrees if OPT = 3
11-20	A(J)	"	z coordinate of point J if OPT = 0, or, r coordinate of point J if OPT = 2, or, body section radius if OPT = 3
21-30	D(J)	"	Δ x shift of point J if OPT = 0 or 2

Card set 4C contains MB cards if OPT = 0 or 2, contains only 1 card if OPT = 3, and is omitted if OPT = 1 or MB <0 on card 4B. See Figure 11.

Card Set 4D - Alternate XYZ Input

Col.	Variable	Value	Description
1-12	D(J)	Arbitrary (floating point)	x coordinate of section
13-24	B(J)	"	y coordinate of point J
25-36	A(J)	"	z coordinate of point J

This card set is omitted unless MB <0 in Card 4B.

Note: Repeat card 4B and card sets 4C or 4D NB times to complete card set 4.

Card Set 5 - Wing Panel Input - This card set allows the wing and vortex lattice panels to be calculated automatically from the wing section data. Three options are available for inputting the wing section geometry. The XYZ program input referred to below conforms with the format of Reference 7. Omit this card set if CASE = 1 on card 2.

Card 5A - Number of Wing Sections

Col.	Variable	Value	Description
1-10	NW	Arbitrary Integer	Number of wing sections ($2 \leq NW \leq 40$)
20	KOORD	1	Wing section ordinates input in percent of local chord
		2	Wing section ordinates input are not normalized

Card 5B - Wing Section Geometry

Col.	Variable	Value	Description
1-10	XBE	Arbitrary (floating point)	x coordinate of origin of wing section coordinate system except blank when XYZ program input format is used
11-20	YBE	"	Similarly the y coordinate
21-30	ZBE	"	Similarly the z coordinate
31-40	CHRD	"	Chord length of section
41-50	ALF	"	Section twist angle (degrees) (twist positive for dz/dx negative)
51-60	XAL	"	Center of twist in percent chord
61-65	MW	Arbitrary Integer	Number of coordinates in section ($5 \leq MW \leq 59$). Always odd number if internal vortices selected. If MW < 0, XYZ input format requested.
70	OPT	0	Wing section ordinates to be used from card set 5D and 5E
		1	Wing section ordinates same as preceding section - card set 5D and 5E omitted
75	FLAG	0	Normal case - vortex lattice panels calculated automatically
		1	Terminal wing section (end of current wing panel network)

Card 5B-Wing Section Geometry (cont'd)

Col.	Variable	Value	Description
		2	No vortex lattice panels calculated for this section
		3	The coordinates of the last bound vortex in the vortex lattice are read in on card 7 for this section
80	DEL	0	No wing dihedral
		1	Dihedral input on card set 5C

Note: The values of CHRD, ALF, and XA1 on card 5B are required only if KOORD = 1 on Card 5A.

Card Set 5C - Wing Dihedral Input

Col.	Variable	Value	Description
1-10	DELTA	Arbitrary (floating point)	Dihedral angle (degrees)
11-20	YO	"	y and z coordinates of axis of rotation of wing panel
21-30	ZO	"	

Omit card set 5C if DEL = 0 in card 5B

Card Set 5D - Wing Section Coordinates (Normal Input)

Col.	Variable	Value	Description
1-10	B(J)	Arbitrary (floating point)	x coordinate of point J
11-20	A(J)	"	z coordinate of point J
21-30	C(J)	"	Vortex lattice strength at point J
31-40	D(J)	"	Δ y shift of point J

Card set 5D contains MW cards if OPT = 0, and is omitted if OPT = 1 or MW<0 on card 5B. See Figure 12.

Card Set 5E - Alternate XYZ Input

Col.	Variable	Value	Description
1-12	B(J)	Arbitrary (floating point)	x coordinate of point J
13-24	D(J)	"	y coordinate of point J
25-36	A(J)	"	z coordinate of point J
51-60	C(J)	"	Vortex lattice strength at point J

This card set is omitted unless MW<0 on card 5B.

Note: Repeat card 5B and card sets 5C, 5D, or 5E NW times to complete card set 5.

Card Set 6 - Vortex Lattice Control Point Location

Col.	Variable	Value	Description
1-10	WAKE	Arbitrary (floating point)	Extension of vortex lattice into wake in percent chord
11-20	POINT	"	Location of vortex lattice control point in percent chord behind trailing edge

Note: These values are not used if FLAG = 3 on Card 5B. Omit card 6 if CASE = 1 on Card 2.

Card Set 7 - Relocation of Vortex Lattice Terminal Points - This card set is omitted unless FLAG = 3 on card 5B. For each wing section having FLAG = 3, two additional cards are required to specify the terminal points of the streamwise vortices.

Card Set 7A - Inboard Terminal Points

Col.	Variable	Value	Description
1-10	XLP	Arbitrary (floating point)	x coordinate of inboard edge of lattice terminal point
11-20	YLP	"	y coordinate of inboard edge of lattice terminal point
21-30	ZLP	"	z coordinate of inboard edge of lattice terminal point

Card Set 7B - Outboard Terminal Points - Same as card 7A for outboard edge of lattice terminal point.

Card Set 8 - Body Vortex Lattice Input - This card set allows additional vortex lattices to be located inside the body of wing-body combinations, and is omitted if CASE <3 on card 2.

Card Set 8A- Number of Streamwise Vortices in Body Vortex Lattice Network

Col.	Variable	Value	Description
1-10	NV	Arbitrary Integer	Number of streamwise vortices in body vortex lattice network ($NV \leq 40$)

Note: The sum of all wing and body vortex lattices may not exceed 35.

Card Set 8B - Vortex Lattice Geometry

Col.	Variable	Value	Description
1-10	XBE	Arbitrary (floating point)	x coordinate of origin of streamwise vortex
11-20	YBE	"	y coordinate of origin of streamwise vortex
21-30	ZBE	"	z coordinate of origin of streamwise vortex
31-40	MV	Arbitrary Integer	Number of bound vortices in lattice $2 \leq MV \leq 60$
41-50	OPT	0	Vortex lattice points to be read from card set 8C
		1	Vortex lattice points same as preceding. Omit card set 8C.
		2	Optional vortex lattice control panel coordinates read on card 8D-3.
51-60	FLAG	0	Normal case - vortex lattice panels calculated
		1	Terminal vortex of current body vortex lattice network
		2	Corner points of control point panel to be read on Cards 8D-2 and 8D-3 (used when arbitrary control point is desired)

Card Set 8B - Vortex Lattice Geometry (cont'd)

Col.	Variable	Value	Description
61-70	SIMPOT	0	Symmetry option specified on card 2 enforced for this vortex
		1	Symmetry option ignored for this vortex lattice (used for inserting vortex lattice networks in vertical tails located in x,z plane)

Card Set 8C - Vortex Lattice Coordinates

Col.	Variable	Value	Description
1-10	B(J)	Arbitrary (floating point)	x coordinate of point J
11-20	A(J)	"	z coordinate of point J
21-30	C(J)	"	Vortex lattice strength at point J
31-40	D(J)	"	Δy shift of point J

Card set 8C contains MV cards if OPT = 0, and is omitted if OPT = 1 on card 8B.

Control Set 8D - Vortex Lattice Terminal Point & Control Point Coordinates

Two or three additional cards are required to specify the terminal point of the streamwise vortex, and the corner points of the lattice control point panel.

Card 8D-1

Col.	Variable	Value	Description
1-10	B	Arbitrary (floating point)	x coordinate of terminal point of streamwise vortex
11-20	A	"	z coordinate of terminal point of streamwise vortex
21-30	D	"	Δy shift of terminal point of streamwise vortex

Note: This point also defines the upstream corner of the control point panel if FLAG ≠ 2 on card 8B.

Card 8D-2 - Same as card 8D-1, containing the coordinates of the downstream corner of the control point panel if FLAG ≠ 2 on card 8B. If FLAG = 2 on card 8B, this card contains the coordinates of the upstream corner of the control point panel.

Card 8D-3- If FLAG = 2 on card 8B, this card contains the coordinates of the downstream corner of the control point panel, in the same format as card 8D-1. Omit this card if FLAG ≠ 2 in card 8B-1.

Note: Repeat card 8B, and card sets 8C and 8D NV times to complete card set 8.

Plot Input Cards - The configuration panel geometry is stored on TAPE 11. If PLOT = 1 on card 2, the plot overlay is called, and a plot tape is written. A sample panel geometry plot is shown on Figure 28. Additional plot input cards required are described below. Omit these cards if PLOT = 0 on card 2.

Card 9 - Plot Parameters

Col.	Variable	Value	Description
1-10	NVU	0	No plot requested; return.
		1-4	Number of view points selected. If NVU positive, only source panels will be plotted. If NVU negative, vortex panels will also be plotted.
	IPRINT	0	Panel corner points are not printed.
		1	Panel corner points printed.
	IHIDE	0	Eliminate hidden surfaces in plot output.
		1	All surfaces plotted.
	IBUG	0	No debug printout from PLOT subroutines.
		1	Additional debug printout requested.

Card Set 10 - View Point Coordinates

Col.	Variable	Value	Description
1-10	VUE(1,NVU)	Arbitrary (floating point)	x coordinate of view point NVU
11-20	VUE(2,NVU)	"	y coordinate of view point NVU
21-30	VUE(3,NVU)	"	z coordinate of view point NVU.

Card Set 10 - View Point Coordinates (cont'd)

Repeat Card Set 10 NVU times.

Any view point coordinate is set equal to infinity if it is greater than 2^{15}. (32,768)

Aerodynamic Input Cards

The configuration panel geometry is transferred to the aerodynamic section of the program TAPE 11. Additional aerodynamic input cards required are described below:

Card 11 - Case Identification Card - Card 11 contains any desired case identification in columns 1-80.

Card 12 - Iteration Option Card

Col.	Variable	Value	Description
1-10	NIT	Arbitrary Integer	Maximum number of iterations
11-20	IEPS	"	Exponent of 10 setting limiting value for residue of iterative solution (-3 or -4 recommended)
21-30	ITYPE	1	Gauss-Siedel iteration procedure
		2	Mixed direct/iterative solution procedure

Card 13 - Configuration Options

Col.	Variable	Value	Description
1-10	COMPT	0	Forces and moments calculated for complete configuration
		Arbitrary Integer	Forces and moments calculated on components. Panel indices of each component follow on card 22
11-20	SECT	0	No wing section forces and moments
		1	Wing section forces and moments calculated. Wing section indices follow on card 21, panel indices in each section on card 22, and section reference lengths on card 25

Card 13 - Configuration Options (cont'd)

		2	Forces and moments calculated on subsections. The number of subsections follow on card 21, the number of panel groups on card 23, the panel indices in each group on card 24, and subsection reference lengths on card 25

Card 14 - Reference Parameters

Col.	Variable	Value	Description
1-10	REFA	Arbitrary (fixed point)	Reference area
11-20	REFI	"	Reference chord (MAC)
21-30	XOO	"	Axial distance of leading edge of MAC from origin
31-40	X25	"	Axial distance of quarter chord of MAC from origin

Card 15 - Configuration Lift Option

Col.	Variable	Value	Description
1-10	KUT	0	Nonlifting configuration, no vortex lattice Kutta condition imposed
		1	Lifting configuration, vortex lattice Kutta condition imposed
		-1	Wing vortex lattice extends through body having same strength as adjacent wing vortex lattice
11-20	NBV	Arbitrary Integer	Number of body vortices (NBV $\leq$ 5)
21-30	NV(1)	"	Number of wing vortices associated with body vortex 1
31-40	NV(2)	"	Number of wing vortices associated with body vortex 2
.	.		
.	.		
.	.		
61-70	NV(5)	"	Number of wing vortices associated with body vortex 5

Card 16 - Compressibility Rule Option

Col.	Variable	Value	Description
1-10	KOMPR	1	Gothert Rule 1 selected (See Text)
		2	Gothert Rule 2 selected (See Text)
11-20	POINTS	Arbitrary Integer	Number of field points following on card set 16A
21-30	NORPAN	"	Number of normal velocities following on card set 16B

Card Set 16A - Field Point Coordinates

Col.	Variable	Value	Description
1-10	XP	Arbitrary (floating point)	Coordinates of field point
11-20	YP	"	" " " "
21-30	ZP	"	" " " "

(Repeat card 16A POINTS times.)

Card Set 16B - Normal Velocity Input

Col.	Variable	Value	Description
1-10	NP	Integer	Panel number
11-20	NORVEL	Arbitrary (floating point)	Normal velocity on panel NP. If NORVEL = 0, the normal velocity is set equal to the normal component of the onset velocity(i.e., Equation 43 is used.)

Repeat card set 16B NORPAN times.

Card Set 17 - Number of Mach Numbers

Col.	Variable	Value	Description
1-10	NMA	Arbitrary Integer	Number of Mach numbers following on card set 18

Card Set 18 - Mach Number

Col.	Variable	Value	Description
1-10	MA	Arbitrary (floating point)	Mach number

Card Set 19 - Number of Angles of Attack

Col.	Variable	Value	Description
1-10	NAL	Arbitrary Integer	Number of angles of attack following on card set 20

Card Set 20 - Angle of Attack or Yaw

Col.	Variable	Value	Description
1-10	ALPHA	Arbitrary (floating point)	Angle of attack in degrees
11-20	BETA	"	Angle of yaw in degrees

Card Set 21 - Number of Sections

Col.	Variable	Value	Description
1-10	IS	Arbitrary Integer	Number of sections; omit if SECT = 0 on card 13

Card Set 22 - Panel Indices

Col.	Variable	Value	Description
1-10	IA	Arbitrary Integer	Index of initial panel in section
11-20	IE	"	Index of final panel in section

Card Set 23 - Number of Panels in Subsections

Col.	Variable	Value	Description
1-10	IREI	Arbitrary Integer	Number of panels in subsections Omit if SECT <2 on card 13

Card Set 24 - Subsection Panel Indices

Col.	Variable	Value	Description
1-5	II (1)	Arbitrary Integer	Panel indices of all panels in subsection; omit if SECT <2 on card 13
6-10	II (2)	"	
11-15	II (3). . . etc.		

Card Set 25 - Reference Lengths

Col.	Variable	Value	Description
1-10	DELY	Arbitrary Integer	Width of section
11-20	REFL	"	Reference length of section
21-30	XLE	"	Moment reference point of section

Cards 21-25 must be repeated for each angle of attack or yaw, if section data requested.

PROGRAM OUTPUT

The standard output of the program consists of a list of the input cards, a table of panel points, a table of velocities and pressure coefficients at panel control points, and a force and moment summary. Additional output may be obtained by selecting appropriate values of the integer PRINT. A sample output is given in Appendix IV.

PRINT = 1	Tables of panel corner points, centroids, and the panel coordinate transformation matrix are printed out. Individual panel forces and moments are also printed out.
PRINT = 2	Tables of panel velocity components and influence coefficients are printed out. This option requires a large line count limit.
PRINT = 3	The aerodynamic influence coefficient matrix is printed out in row order, together with the right side of the matrix equation, and all solution iterations.
PRINT = 4	This option prints out the successive solution iterations only.

PROGRAM TIME ESTIMATION

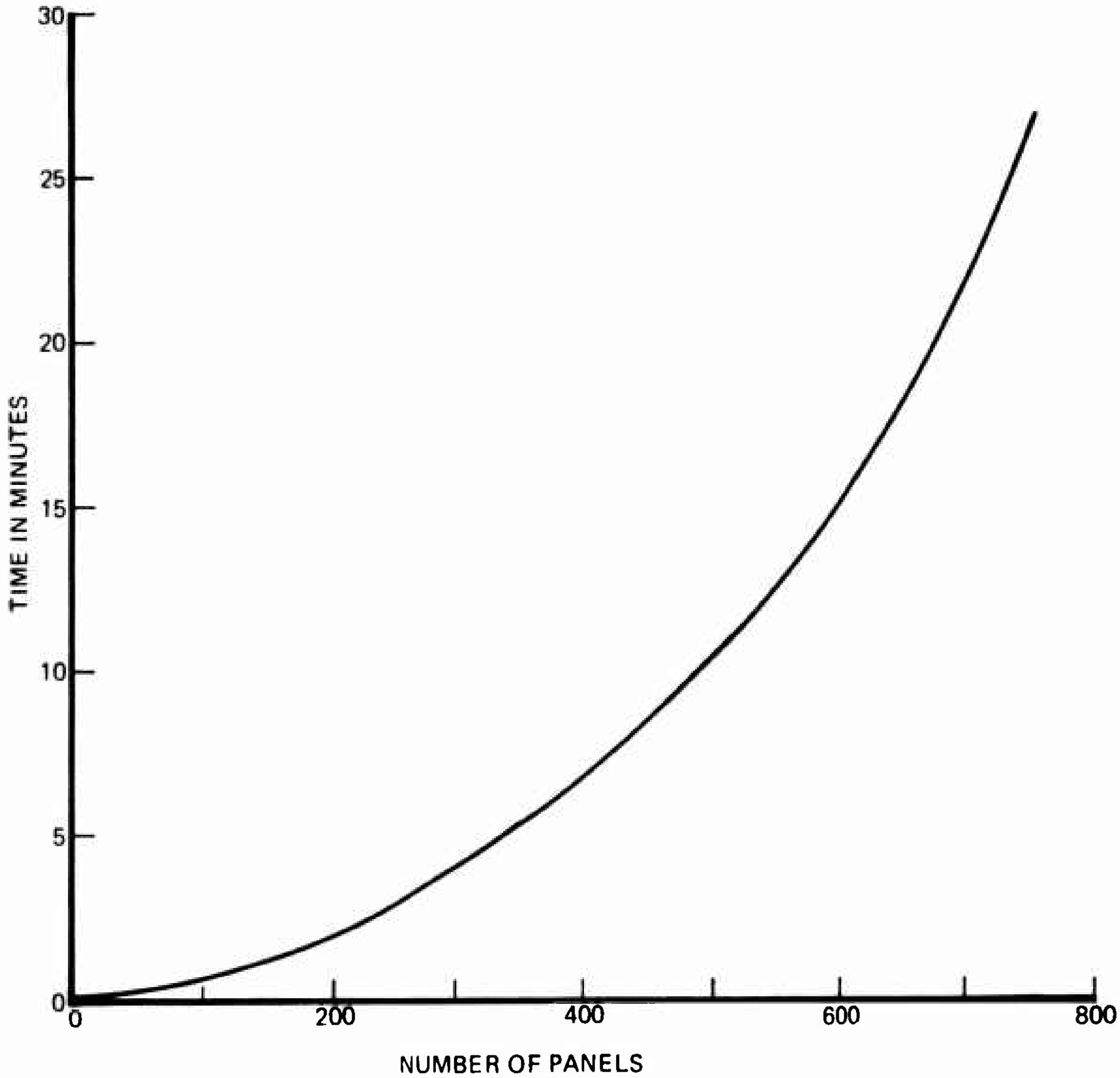
Estimates of the CPU time required by the CDC 6600 computer to calculate the aerodynamic matrix and solve for one angle of attack or yaw are presented on Figure 10. If the configuration is symmetric about the x,z plane and the yaw angle is zero, the flow is symmetric. Use of this fact by the program reduces the running time. This reduction is reflected in Figure 10 by the fact that only the number of source and vortex panels on one side of the x,z plane are counted for the symmetric flow case.

PROGRAM USAGE

The success of this method of analysis depends to a large extent on the choice of the number and location of panels used to represent the configuration. Certain features of the program input will be described in this section, together with recommendations on program usage.

Body Input

The body is described by a series of cross-sections given at selected intervals along its length. The surface panels are located between



NOTE: FOR YAW CASES AND FOR UNSYMMETRIC CASES, COUNT ALL PANELS.

FOR SYMMETRIC, UNYAWED CASES, COUNT PANELS ON ONE SIDE OF SYMMETRY PLANE ONLY.

Figure 10. CPU Time Required for CDC 6600.

adjacent sections, with the corner points being defined by the cross-section coordinates. Unless the cross sections can be described by some mathematical formula, accurate drawings are required for each body station. The cross section can be defined either in Cartesion (y,z) or polar (r,θ) coordinates about the body reference axis. A maximum of 70 stations may be used along the length of the body, and a maximum of 60 points around the half circumference.

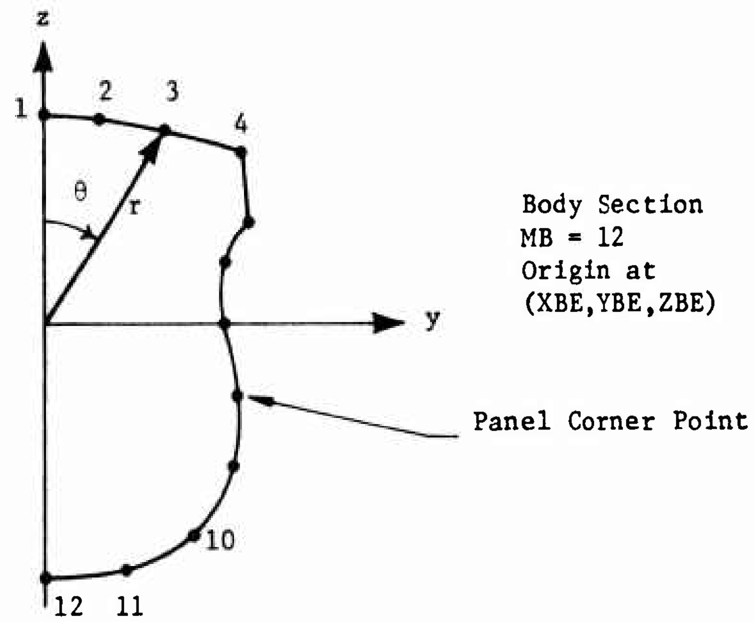


Figure 11. Body Cross Section.

In general, more panels are required in regions with rapid changes of cross sectional shape, such as around canopies or wing-body intersections.

The program does not require the same number of panels in each circumferential ring, and a special input option is provided to identify the sections at which the number of panels is being increased or decreased.

In addition, the panel corners may be shifted lengthwise out of the plane of the defining section. This option allows more freedom for paneling complex wing-body intersections and fairings.

Wing Input

The wing is described by a series of airfoil sections given at selected intervals along the span. The surface panels are located between adjacent sections, with the corner points being defined by the section coordinates. The section coordinates may be given in percent chord or directly in terms of the reference coordinate system. The panels in each wing section are generally numbered sequentially from the trailing edge on the lower surface around the leading edge to the trailing edge on the upper surface. The same number of points at approximately the same percent chord locations must be used to define the wing upper and lower surfaces, since the vortex lattice panels on the mean camber surface are defined by averaging the upper and lower surface points. A maximum of 60 points may be used to define each section, and a maximum of 40 sections may be defined on the half-wing.

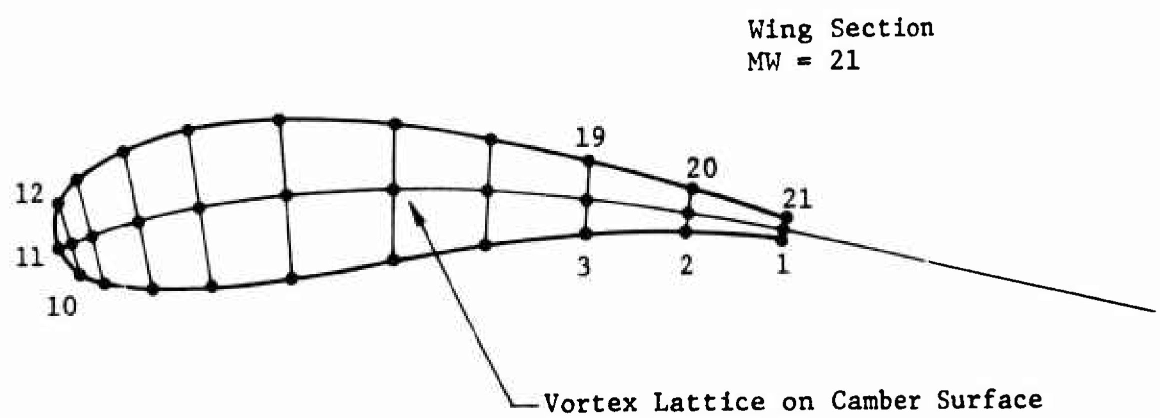


Figure 12. Wing Section.

The program does not require the same number of points on adjacent wing sections, and a special input option is provided to identify the sections at which the number of panels is being increased or decreased. In addition, the panel corners may be shifted spanwise out of the plane of the defining section to aid in the paneling of wing tips or complex wing-body intersections. In general, more panels are required in regions of rapid curvature, for example, the leading edge region.

Wing tip paneling may be omitted for wings having a maximum thickness of less than 5%. However, wing tip panels can be included as special body panels, or read in individually using the single panel input option.

<u>Vortex Lattice Panels</u>

Vortex lattice panels may be placed inside either the wing or body, or omitted entirely. For configurations with a wing, the vortex lattice panels are automatically located on the mean camber surface of the wing. The vortices extend a finite distance behind the wing in a plane passing through the trailing edge and bisecting the trailing edge angle. The vortices should be allowed to extend at least ten chord lengths behind the wing to give a reasonable approximation of the wake. A control panel is associated with each vortex lattice and sized such that the panel control point is located one percent of the local chord behind the trailing edge of the wing.

The relative strengths γ_i of the individual bound vortices making up the vortex lattices must be specified in advance. It is recommended that these strengths be proportional to the airfoil thickness at the chordwise location of the bound vortex. The accuracy of the final solution depends to some extent on the vortex distribution selected, so some adjustment to the bound vortex strengths may be necessary if a poor initial choice has been made.

The program requires that the γ array be read in order of increasing chordwise station. Since the wing numbering system starts at the trailing edge, the first (M+1)/2 points are set equal to zero, and the desired γ array associated with the remainder.

The structure of a vortex lattice is illustrated in the following sketch.

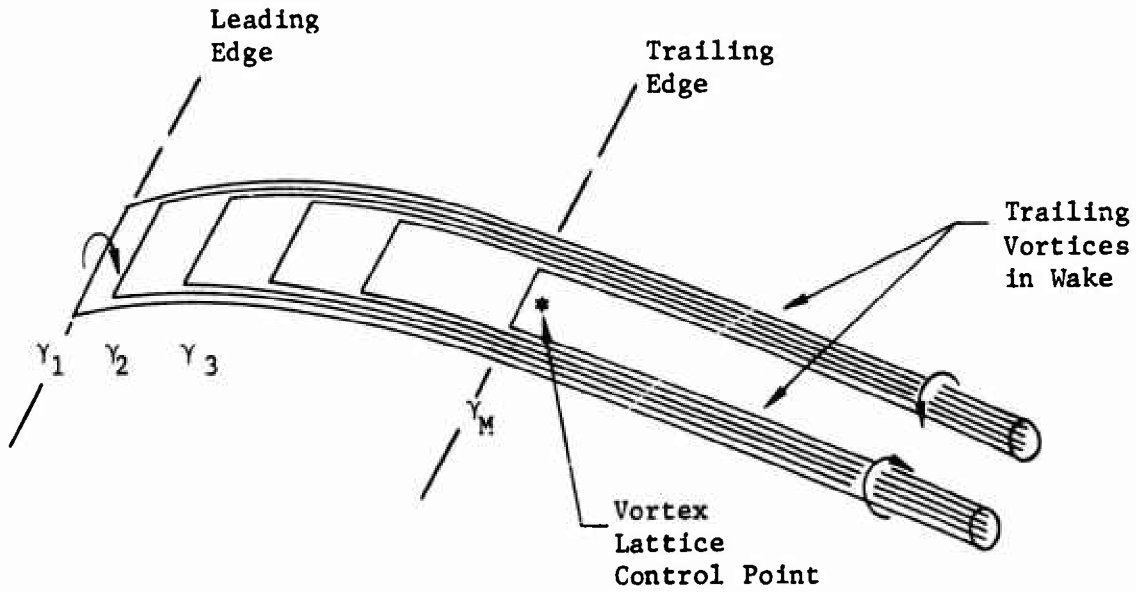


Figure 13. Wing Vortex Lattice.

It can be seen that the trailing vortices in the wake are made up of the sum of the streamwise legs of the individual bound vortices.

Vortex lattices may also be added inside the body to provide a mechanism for generating body lift. For wing-body combinations, a special option is provided to give the body vortex lattice the same strength as the adjoining wing vortex lattice, so that the inboard

trailing vortex from the wing vortex lattice will be exactly cancelled by the outboard trailing vortex from the body vortex lattice.

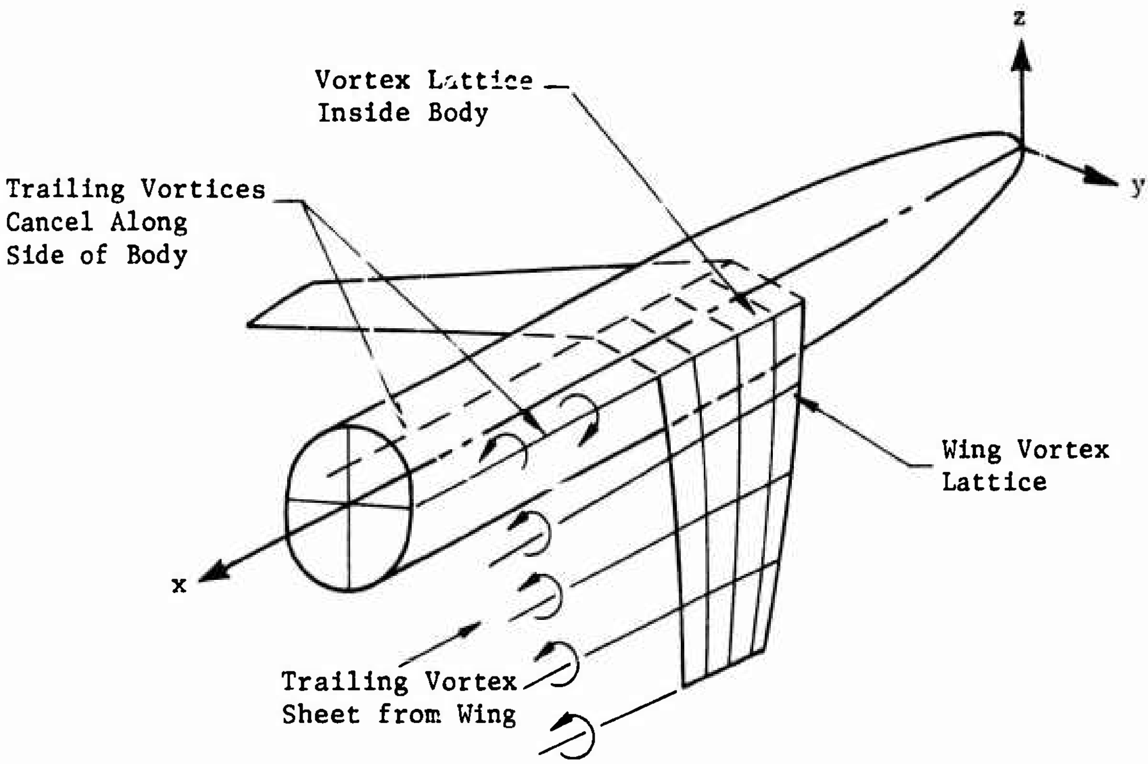


Figure 14. Vortex Lattice Inside Body.

Body vortices are also used to generate the circulation about vertical tails located in the plane of symmetry for yawed configurations. This technique must be employed since the wing vortex lattices defined by the program will automatically cancel in the plane of symmetry. For

unyawed configurations, however, no wing or body vortices may be used in vertical tails located in the plane of symmetry. The use of body vortices in a vertical tail is illustrated in Figure 15.

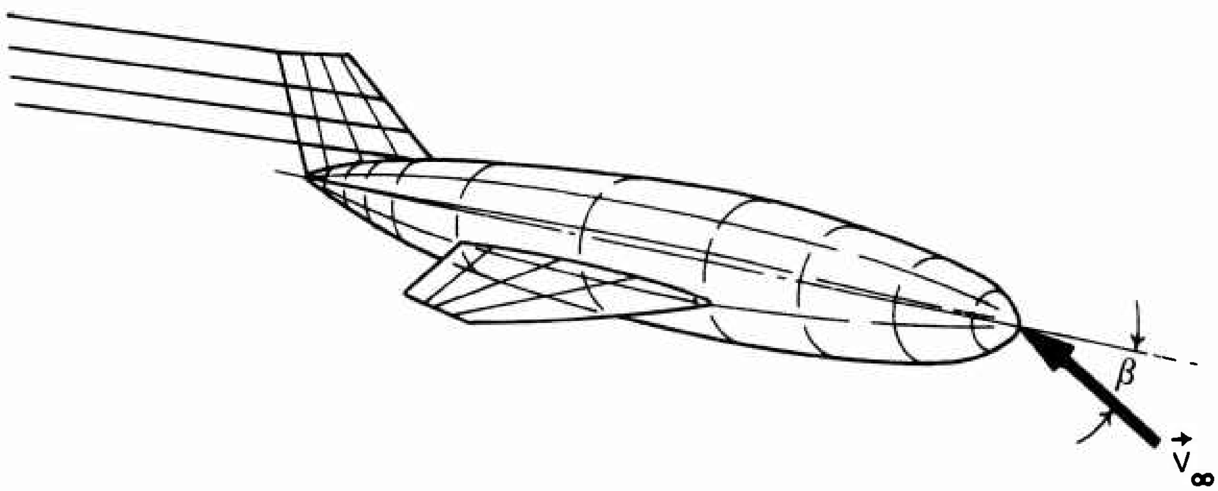


Figure 15. Vortices in Vertical Tail.

For configurations having wings, horizontal tails, and vertical tails, and employing body vortices to carry the lift generated by the wing and horizontal tail through the body, the body vortices used to provide lift on the vertical tail must be input after the body vortices associated with the wing or horizontal tail.

A GENERAL GUIDE TO PANELING WING-BODY-NACELLE CONFIGURATIONS

An input option is available to take advantage of symmetry. With the x z plane in the plane of symmetry, only the half of the configuration corresponding to positive y is required as input. This rule applies whether or not the free stream is in the plane of symmetry (i.e., with or without yaw).

When paneling a particular configuration, attention should be paid to the principal regions of interest, since this allows for optimum use of the total number of panels. A denser panel distribution should be used in the region of interest and a lesser number of panels in regions removed from this region. A sparse panel distribution has a substantial local effect. When choosing the number of panels to be used in each region, it is important to realize that the pressure calculated at the centroid of each panel is assumed to exist over the entire panel. Therefore, more panels are required in regions of large pressure gradients.

The three-dimensional potential flow program usually accepts panel corner points as inputs. An exception to this is the case where a particular section is defined as a circular arc, which may then be specified along with the number of equispaced panel corner points along the circle. The program accepts the defined panels in networks - each network defining a specific region of the configuration. The networks when assembled together define the complete configuration.

In setting up the complete paneling scheme for a wing-body-nacelle configuration, it is usually best to define the nacelle, wing, and body as separate sets of networks. The regions where two bodies intersect are then treated separately, and the particular networks require redefining. Any fairings that exist are treated as part of the particular configuration and not as a separate configuration. Each fairing is usually specified by its own network (or set of networks) of panels.

The body, or most likely half-body, is usually paneled by specifying the buttock line (y) and waterline (z) coordinates at each body station (x), such that at each body station the panel points are equispaced. (It is not necessary to have the panels equispaced, but it is often more convenient.)

The nacelle is paneled in a manner similar to the body.

The wing is usually paneled by specifying the x and y coordinates at each buttock line (y). When defining the panels, it must be remembered that more panels are required at the leading edge, where the pressure gradients are large. The panel size should not vary by more than 50%

(larger or smaller) from any adjacent panel. It is common practice to have no panel larger than 5 percent of the wing chord. Constant spacing is the optimum scheme for spanwise paneling.

The paneling at the intersection of two segments requires special care. For the case of wing-body intersection, the body panels above and below the wing must be adjusted to account for the area eliminated by the intersection. At each body station (x), the y and z coordinates are adjusted to give approximate equispacing above and below the intersection. For the wing segment, the existing paneling can be maintained. All intersections are treated in this manner.

The wing requires a system of multihorseshoe vortices, placed inside the wing with the trailing vortices emanating from the trailing edge, to produce lift. The number of chordwise locations of the internal bound vortices are chosen to minimize large local disturbances at the wing surface. The vortices are placed along the camberline, equidistant from the nearest panel corner points in the chordwise direction.

Additional segments may be added to the configuration, such as a vertical tail and a horizontal tail. The intersections of the various segments are treated as above; and both horizontal and vertical tails will require internal vortex lattices to produce lift. No vortex lattices are placed in vertical tails located in the plane of symmetry unless the configuration is yawed.

It should be noted that, except for the simplest configurations, the preparation of the input to the three-dimensional potential flow program is cumbersome and usually almost always requires the aid of auxiliary geometry manipulation computer programs. The use of the three-dimensional plotting program is also almost essential to check the panel input data.

Save Tape Option

Since a major portion of the computer time is taken up by the calculation of the aerodynamic matrices, provision is made for saving these matrices on magnetic tape for subsequent runs on the same configuration. A new tape must be generated for each Mach number, however. The program stores the aerodynamic matrix on auxiliary disc file TAPE 10, the geometric data on auxiliary disc file TAPE 11, and the velocity component matrices on auxiliary disc file TAPE 12. If the save tape option is selected, ISAVE = -1, a magnetic tape must be designated to replace the disc file TAPE 11. The contents of TAPE 10 and TAPE 12 are also transformed to this tape during the run.

On subsequent runs, the contents of the tape must be transferred back

to the three disc files, and the program rerun with ISAVE = 1. Only the first two cards from the geometry input and the aerodynamic input (Cards 11-25) are required if this option is selected.

COMPARISON WITH EXPERIMENT

The purpose of this section is to aid the reader in the evaluation of the computer program. Discussion of comparisons between theory and experiment will be limited to two specific configurations, although many configurations have been investigated at various times using computer program WBAERO.

BO 105 HELICOPTER CONFIGURATION

The geometry analyzed is shown in its paneled configuration in Figure 16. The number of panels on one side of the plane of symmetry is 256. The results for calculations with separation modeling were given eariler (see Figures 7 and 8) in the explanation of this modeling. Calculations with no separation modeling are compared with experimental data in Figures 17 through 20 for the cases of angle of attack $\alpha = 0^\circ$, and angle of yaw $\beta = 0^\circ$, as well as $\alpha = 0^\circ$, $\beta = \pm 10^\circ$. Calculations have also been made by Gillespie (8) for the same configuration using the Douglas Neumann program, and these have been included for comparison purposes. In Figure 17, calculated and measured pressure coefficients are shown as a function of axial distance for the BO 105 fuselage top centerline with $\alpha = 0^\circ, \beta = 0^\circ$. Since the Douglas Neumann and WBAERO programs are fundamentally identical for the nonlifting case, it would be expected that the calculated results should be identical. On closer scrutiny, however, it is realized that the programs actually differ in two respects. First, WBAERO used the exact expression for the velocity perturbation due to a source for a greater distance away from the source panel than does the Douglas Neumann program; and second, the iterative techniques used by each program in inverting the influence coefficient matrix are different. While the latter difference does not necessarily affect the accuracy of solution, the employment of different expressions for the velocity perturbation will most certainly affect accuracy, and it is reasonable to expect WBAERO to be slightly more accurate than the Douglas Neumann program. Such appears to be the case for the data of Figure 17, at least until the region of flow separation is approached. Comparisons are shown for the same angles of attack and yaw in Figure 18 for pressure coefficients along Waterline 10 (see Figure 16). As in Figure 17, both methods are in good agreement with experiment. A further possible reason for the slight discrepancy between the two calculation procedures results from the panel distribution used to represent the geometry. Identical panel distributions were used in each program up to axial station 32; from that point on slightly different panel arrangements were used to represent the body closure.

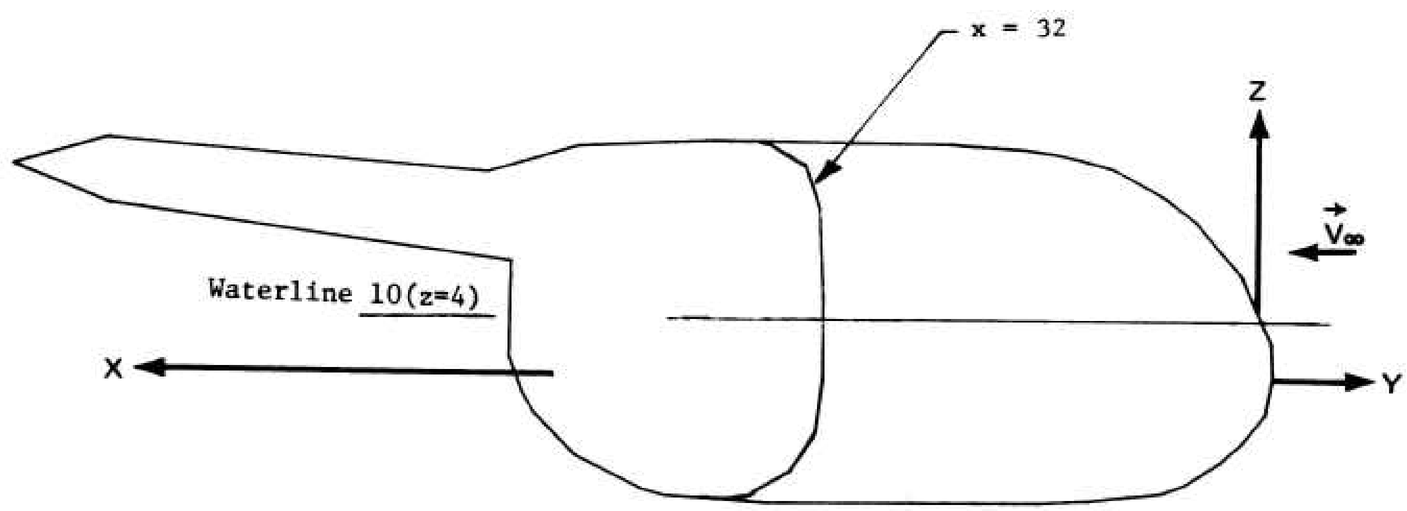


Figure 16. Panel Representation for BO 105 Helicopter Configuration.

Additional calculations were made for comparison with measurements at $\alpha = 0^\circ$, $\beta = 10^\circ$. As shown in Figure 19, agreement between theory and experiment for pressures along the top centerline is quite good. Comparisons between theory and experiment for both windward and leeward sides of the BO 105 fuselage at Waterline 6 show good agreement as seen on Figure 20.

HEAVY LIFT HELICOPTER (HLH) CONFIGURATION

This configuration is shown as paneled in Figure 21. The number of panels on one side of the plane of symmetry is 665. In the analysis of this configuration the boundary condition discussed in the section on separation modeling was used in order that large suction pressure peaks could be avoided at sharp corners. In regions immediately behind these corners the condition $\vec{V} \cdot \vec{n}$ is everywhere zero has been relaxed such that $\vec{V} \cdot \vec{n} = \vec{V}_\infty \cdot \vec{n}$. Separated flow regions on the wings as on the nacelle struts have not been modelled at this time. Calculations have been performed for zero yaw at two angles of attack, $\alpha = 0, -8^\circ$. The results of this analysis are compared with experimental data obtained from Reference 9 at various locations on a 1/12 scale HLH configuration as shown in Figures 22 through 27. Theoretical and measured pressure coefficients along the front pylon top centerline are shown in Figure 22. Agreement between theory and experiment is quite good in the region ahead of axial station 10. At approximately that location the wind tunnel model has an attachment for the forward hub which was not modelled in the potential flow calculations. Consequently, the calculated pressures are not expected to be in close agreement with experiment in the local region behind the hub attachment. Calculations along the front pylon bottom centerline (Figure 23) give a good indication of the effect of sharp corner modelling on the comparisons with experiments. In this case the calculation by Gillespie using the XYZ program (Reference 7) shows a large suction peak around the sharp corner of the fuselage leading to the hoist operator's observation window. The calculations using WBAERO while showing some overshoot in pressure are in much better agreement with experiment, while at the same time taking less computer time because of the more accurate modelling of the real flow. Figures 24 and 25 give the results of comparisons between theory and experiment for the wing upper and lower surface pressures. Although separation effects were not modelled except behind sharp corners, WBAERO is generally in good agreement with experiment. Further comparisons have been made for the nacelle at the maximum spanwise location. Again, the effect of a sharp corner has been accounted for, with excellent results as shown on Figure 26. Measured and calculated pressure coefficients have also been compared along waterlines for the aft pylon. In Figure 27, the comparison is for a waterline just above the

nacelle strut. One particularly interesting result of this comparison is the suction peak resulting from interference by the nacelle strut which is predicted by theory. Because of the choice of pressure tap locations, no indication of this peak can be obtained from data alone. If load calculations are made from such measurements, erroneous conclusions can be drawn.

SAMPLE CASE

A simple wing-body-vertical-tail airplane configuration (Figure 28) has been analyzed as a sample case in order to demonstrate most of the program features. Because configurations having large vertical tails or pylons are expected to experience side forces under yawing conditions, it was necessary to modify the computer program in order that vortex networks could be employed to provide the correct circulation for side force calculations. Calculations are shown in Figure 29 for the pressure distribution along a waterline on the vertical tail. Two calculations are given, for the conditions $\beta = 0^\circ$ and $\beta = 10^\circ$. It is interesting to note that for $\beta = 10^\circ$ the vertical tail carries a negative load on the aft portion. Slender wing theory for low aspect ratio wings suggests that there should be no load over the aft part of the wing; however, interference with the blunt based fuselage appears to lead to the negative load.

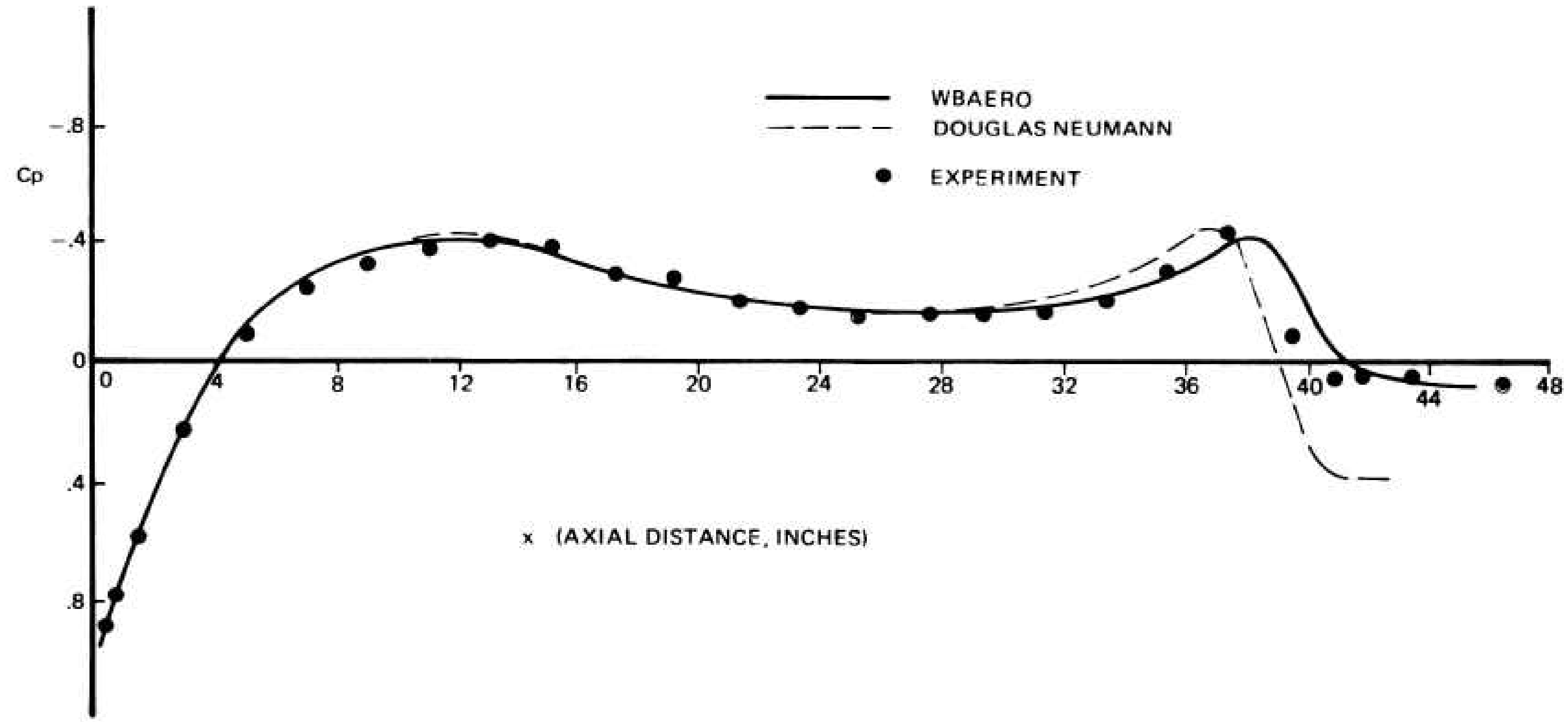


Figure 17. Pressure Distribution for BO 105 along Fuselage Top Centerline $\alpha = 0^\circ$, $\beta = 0^\circ$.

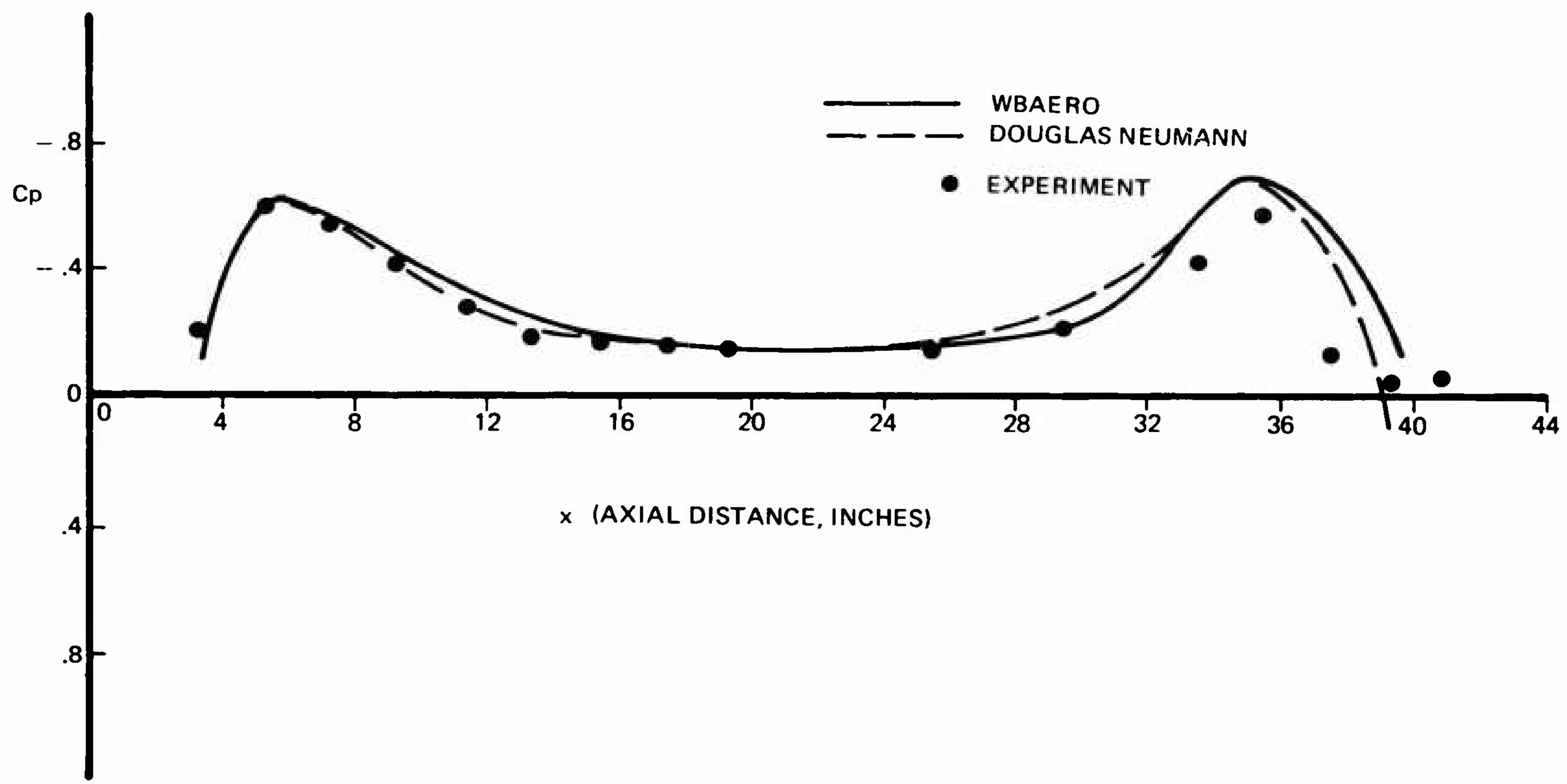


Figure 18. Pressure Distribution for BO 105 along Fuselage Waterline 10 $\alpha = 0^\circ$, $\beta = 0^\circ$.

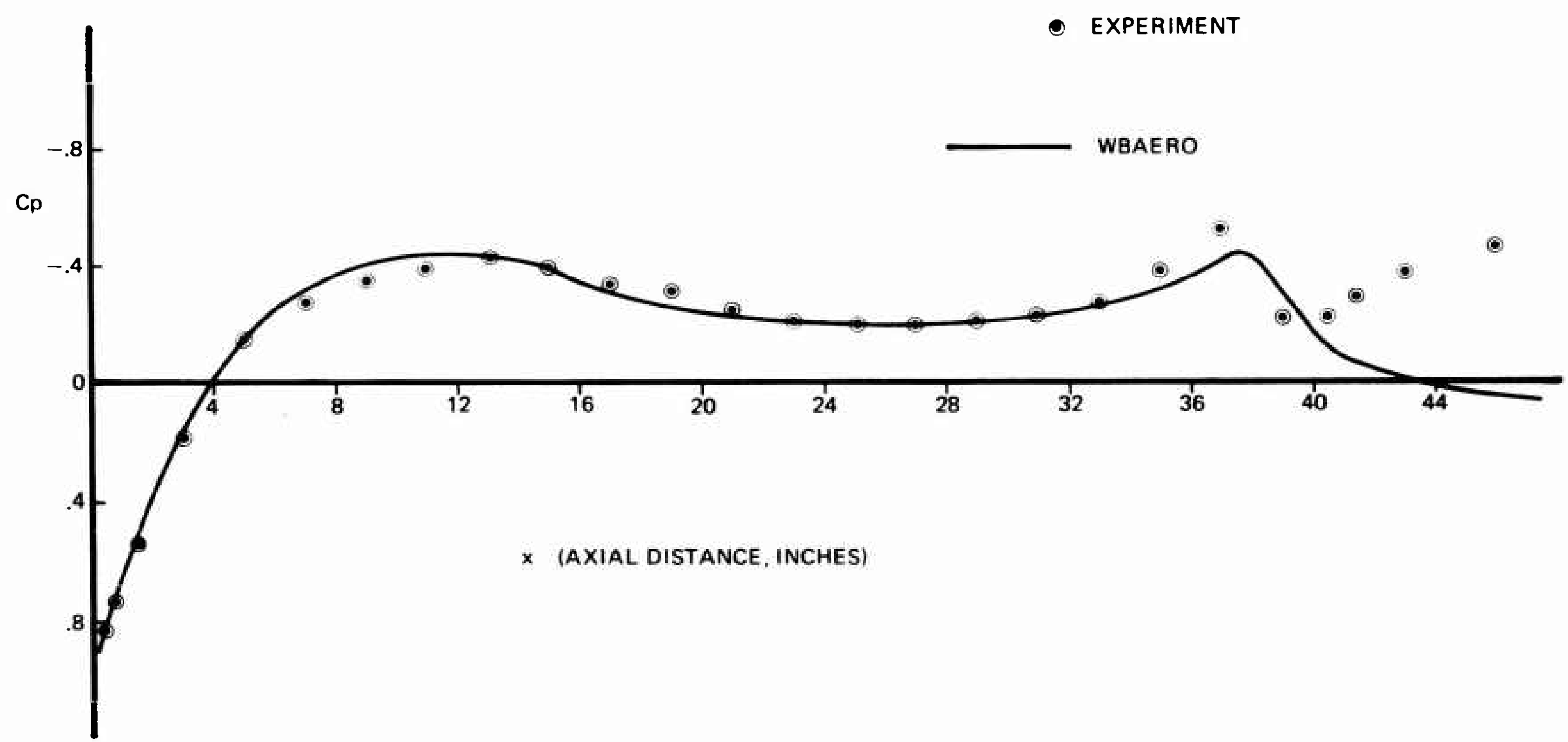


Figure 19. Pressure Distribution for BO 105 along Fuselage Top Centerline $\alpha = 0^\circ$, $\beta = 10^\circ$.

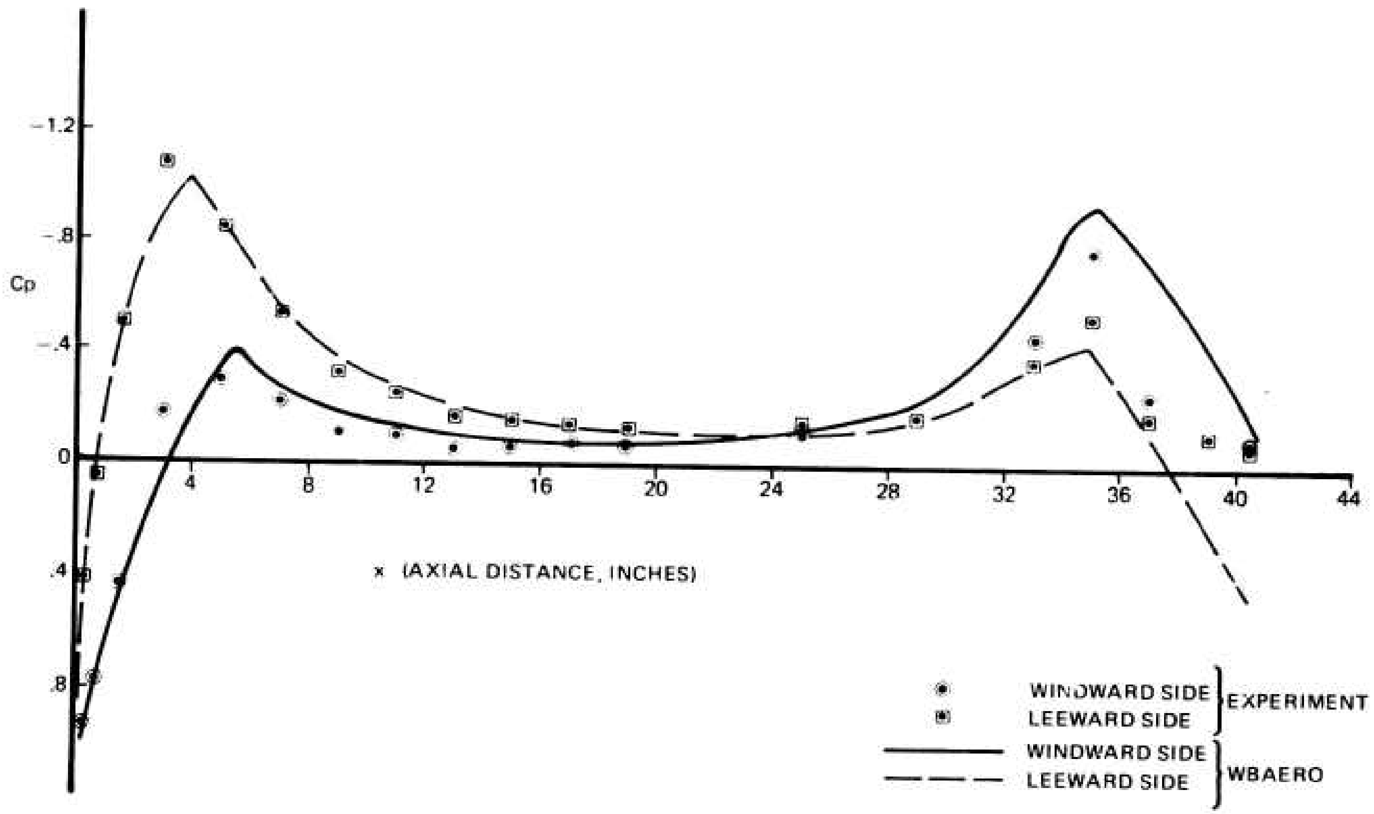


Figure 20. Pressure Distribution for BO 105 along Fuselage Waterline 6 $\alpha = 0^\circ$, $\beta = 10^\circ$.

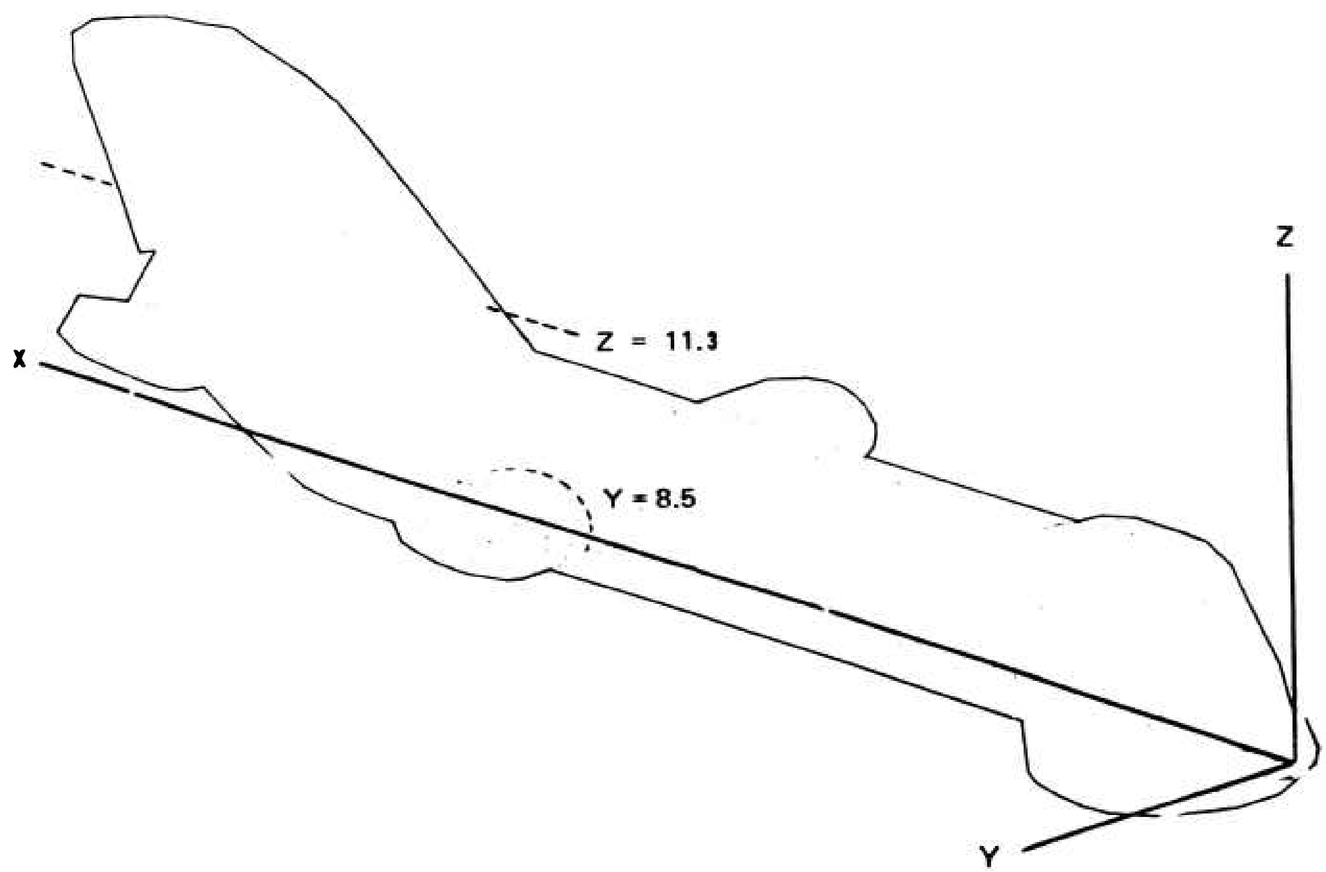


Figure 21. Panel Representation for HLH Configuration.

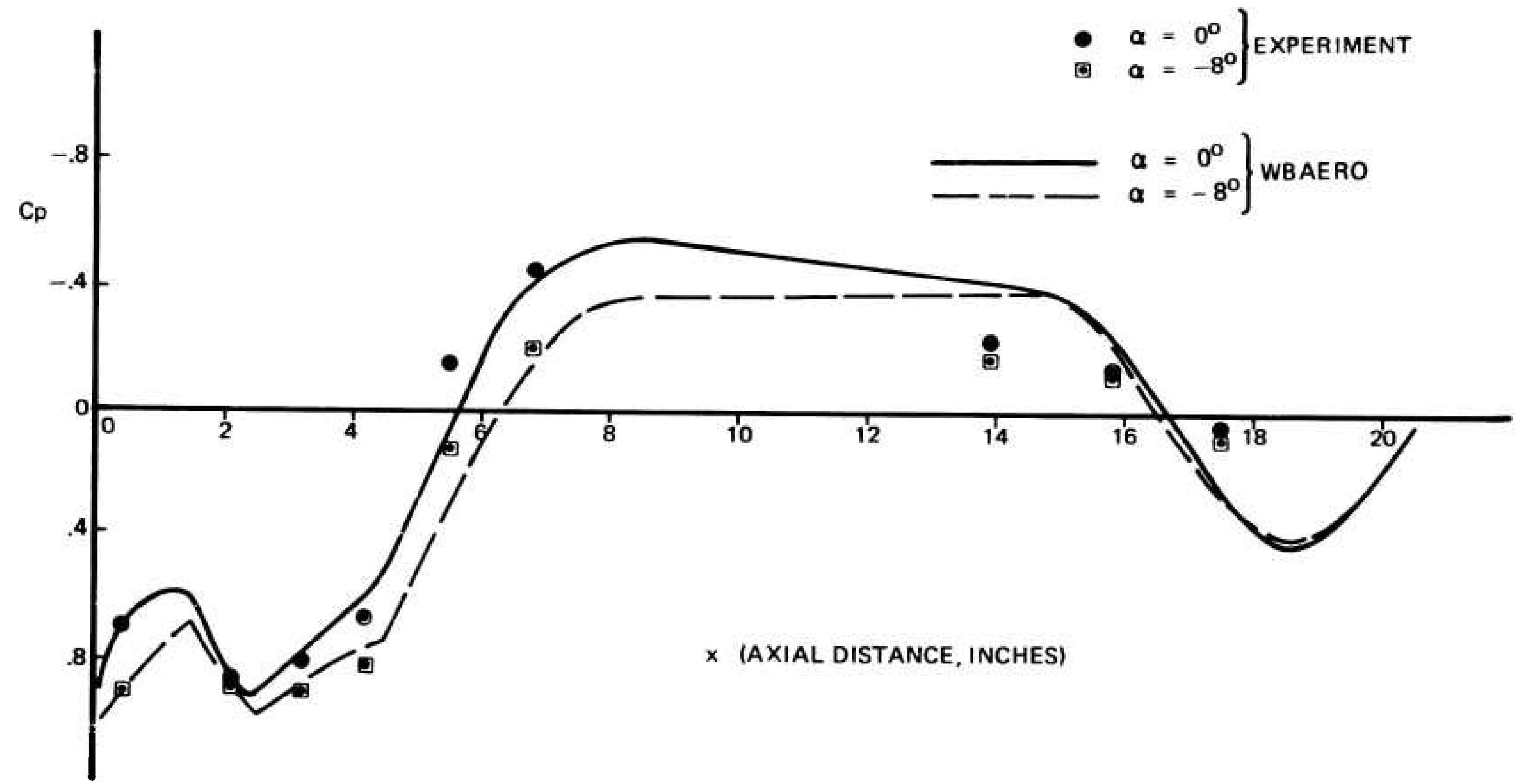


Figure 22. Pressure Distribution for HLH Fuselage Front Pylon Top Centerline.

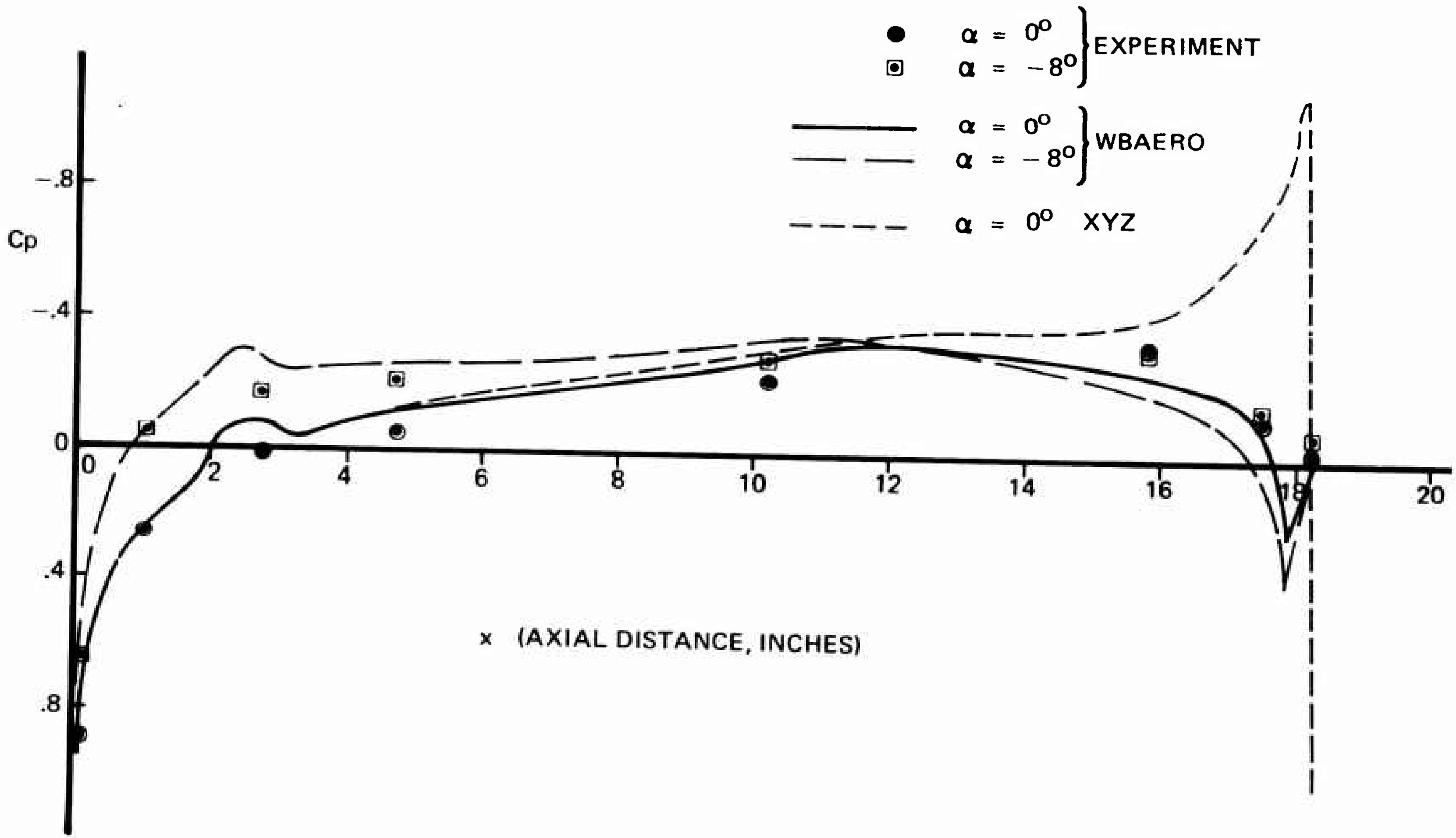


Figure 23. Pressure Distribution for HLH Fuselage Front Pylon Bottom Centerline.

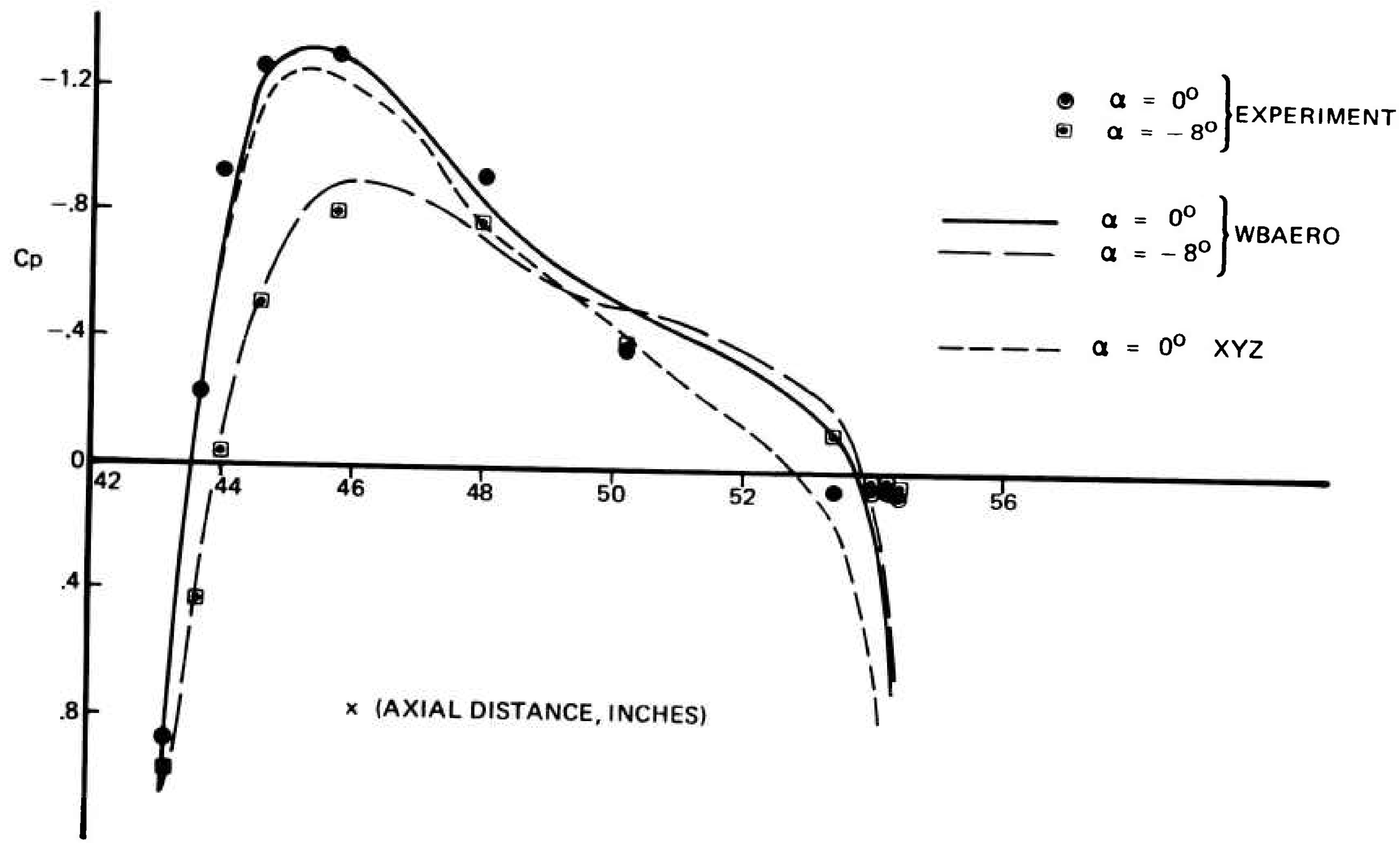


Figure 24. Pressure Distribution for HLH Wing Upper Surface
Y = 8.5.

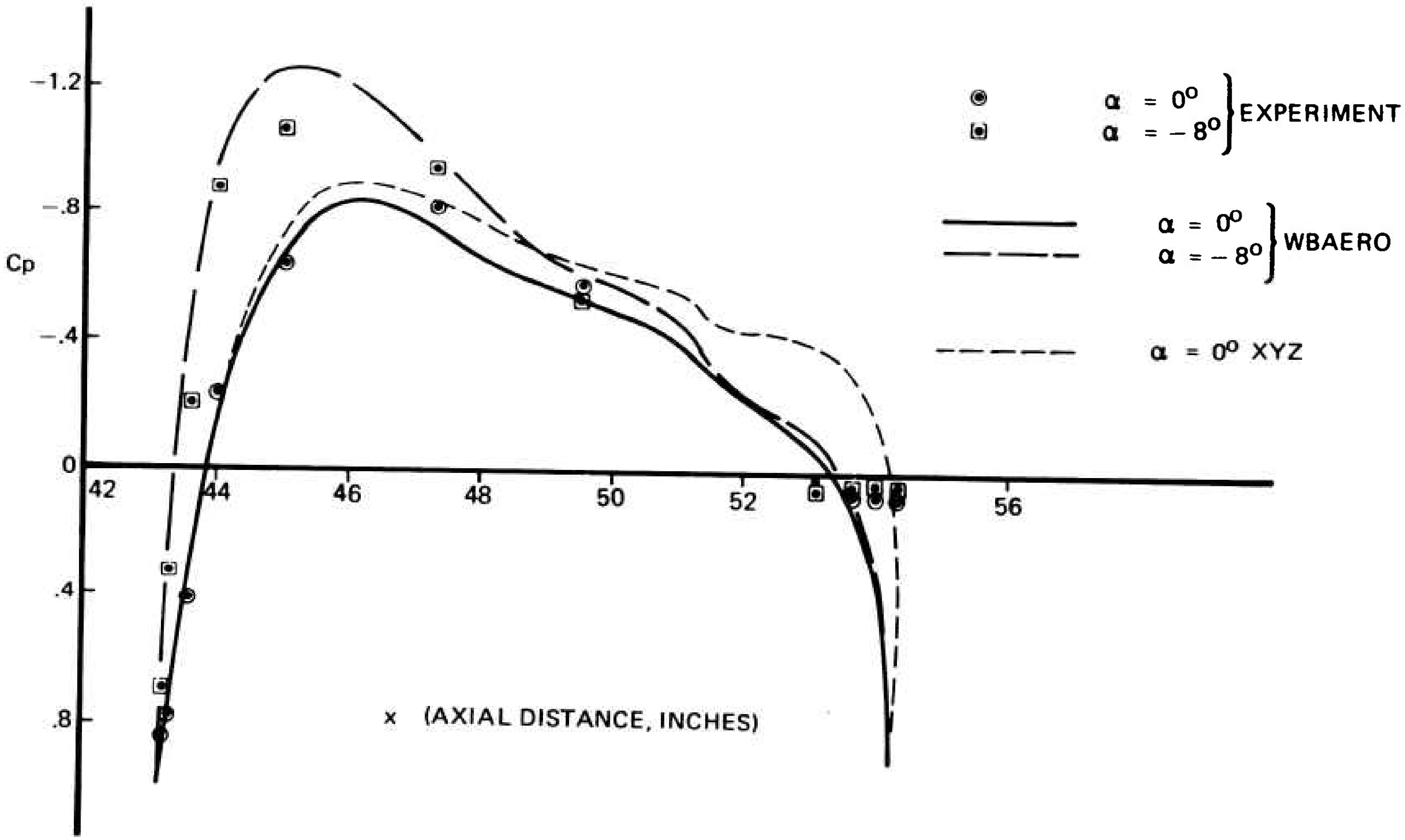


Figure 25. Pressure Distribution for HLH Wing Lower Surface
Y = 8.5.

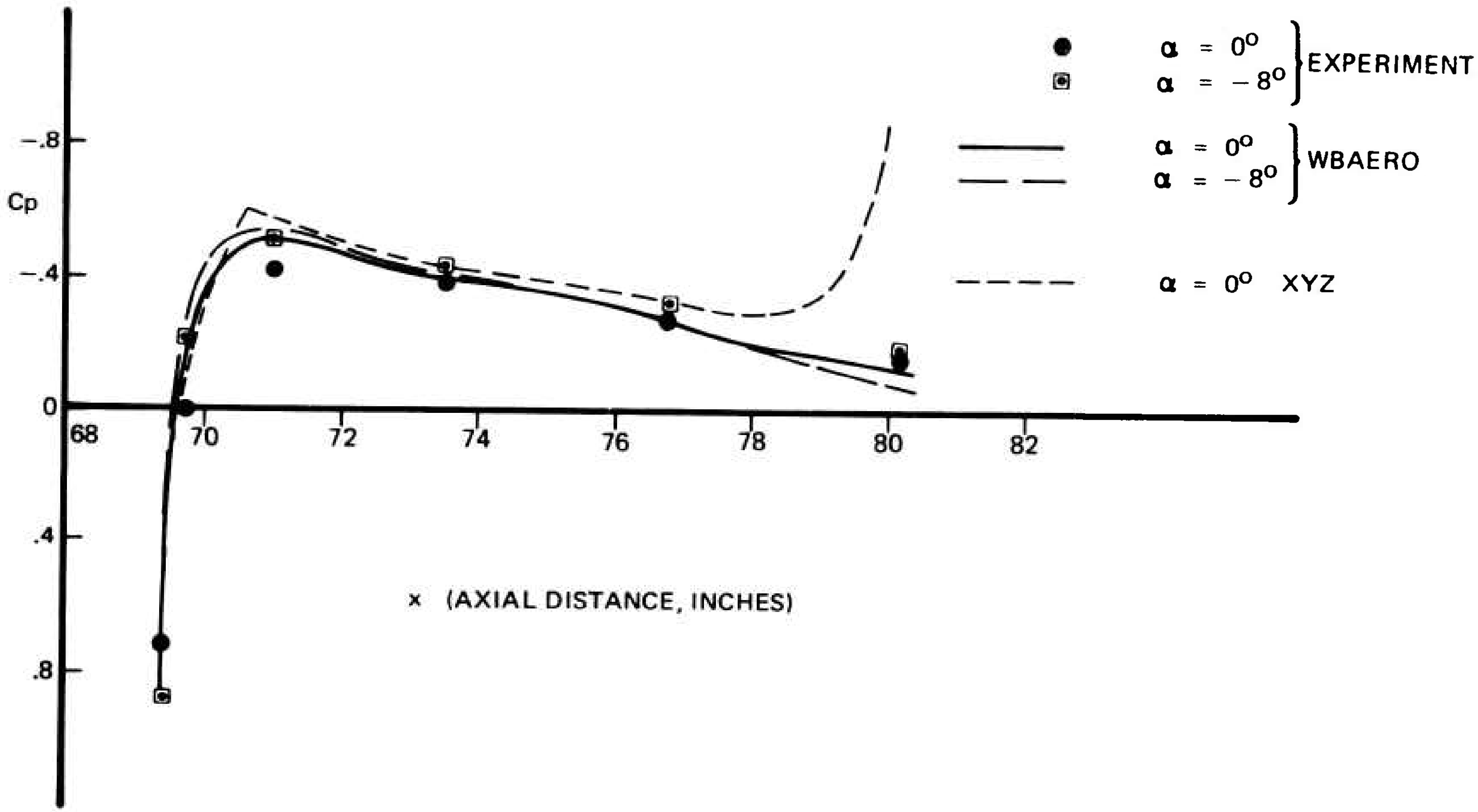


Figure 26. Pressure Distribution for HLH Nacelle - Maximum Span.

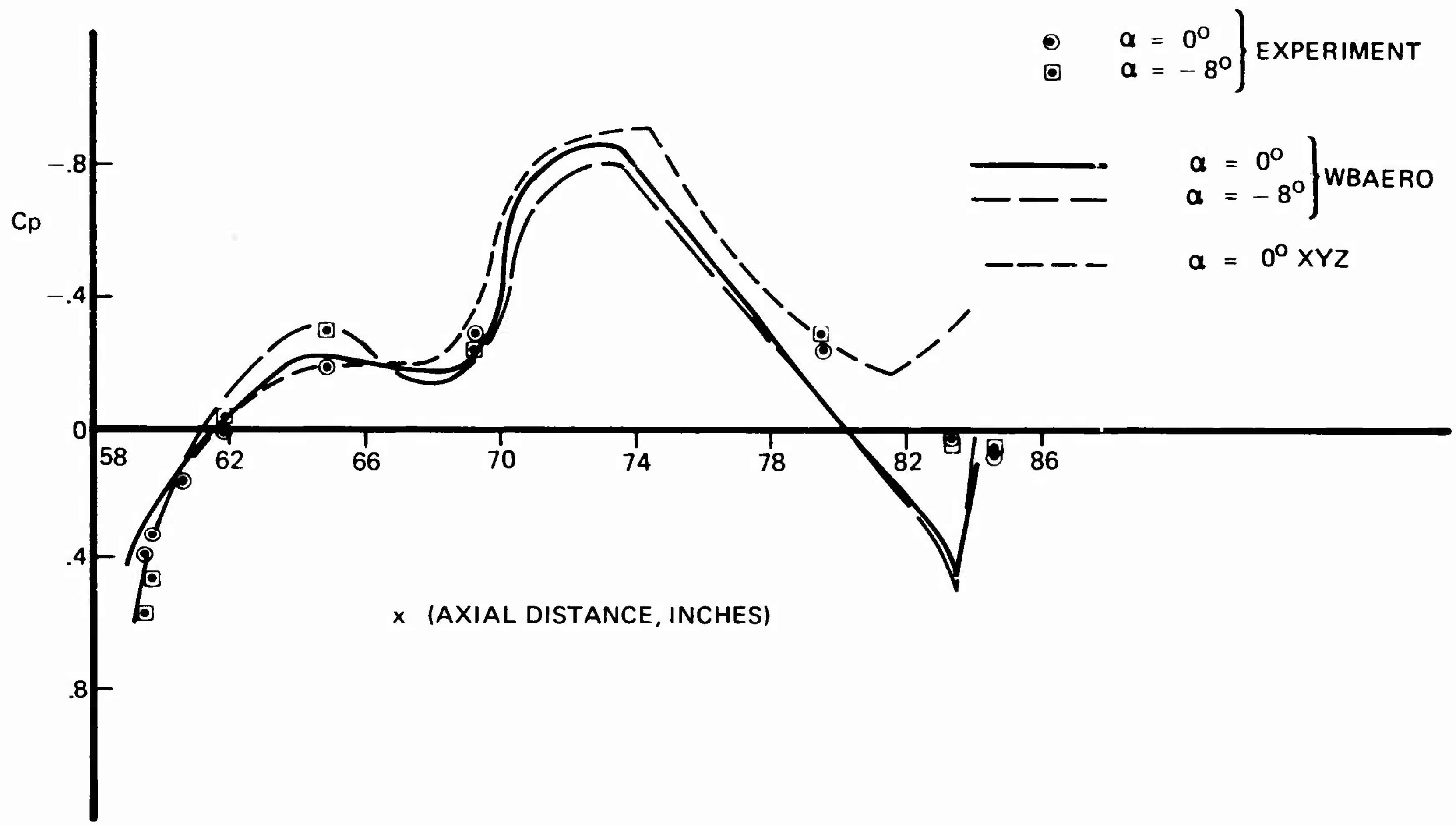


Figure 27. Pressure Distribution for HLH Aft Pylon Above Nacelle Z = 11.3.

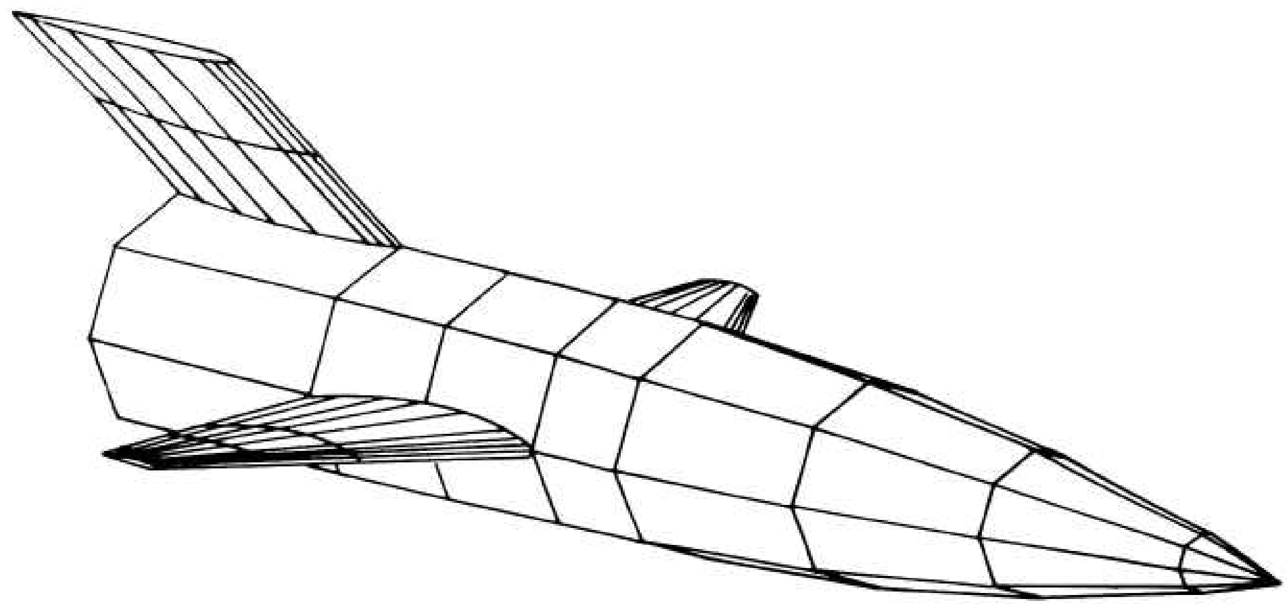


Figure 28. Panel Representation for Wing-Body-Vertical Tail Combination.

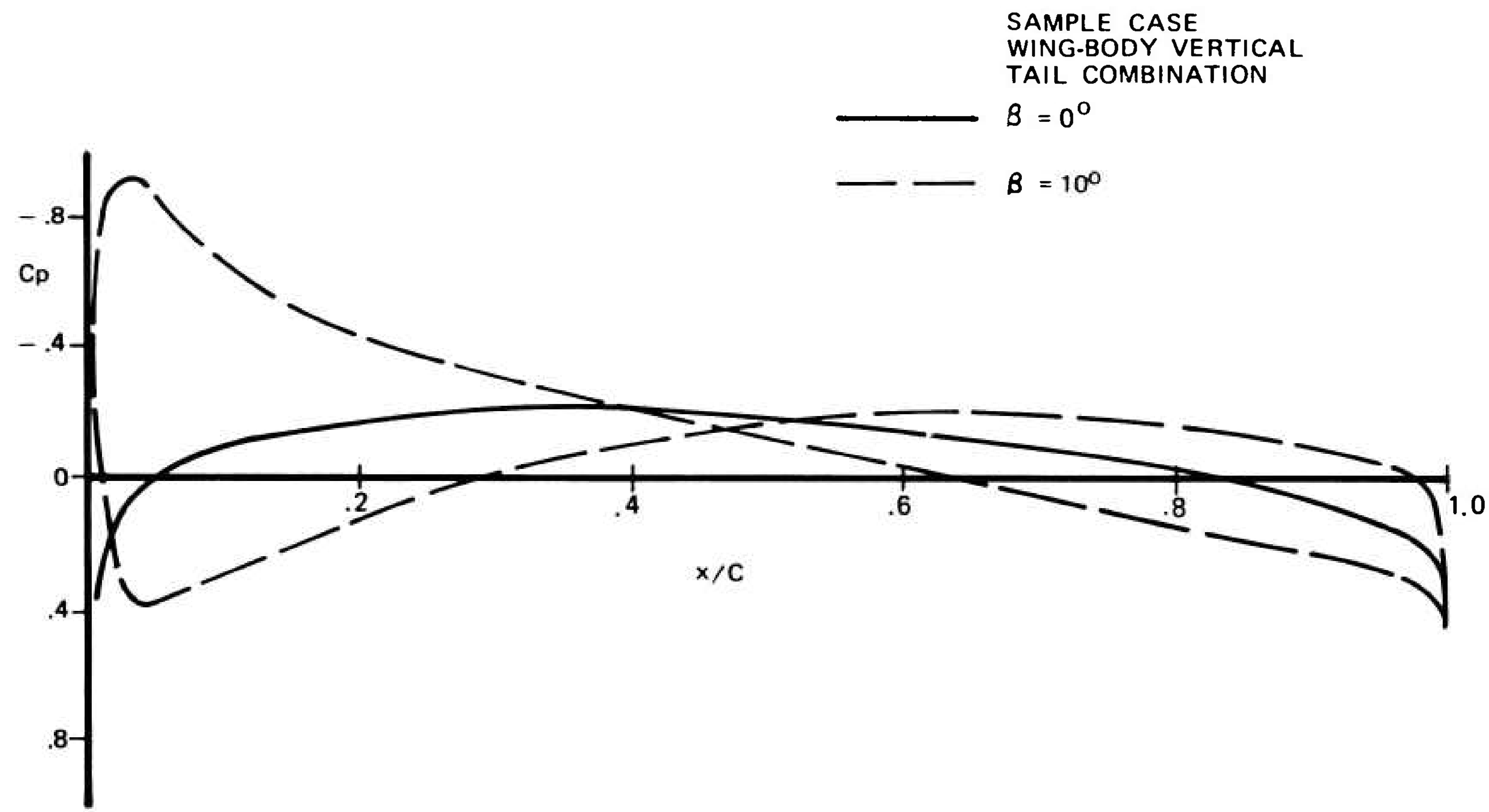


Figure 29. Pressure Distribution on a Low Aspect Ratio Vertical Tail.

CONCLUSIONS

As a result of the studies described in this report, the following conclusions have been drawn:

1. The three-dimensional potential flow computer program provides the user with a practical and accurate method for the calculation of pressures and aerodynamic forces for arbitrary shaped lifting configurations including the effect of yaw.

2. The separation modelling proposed in this report shows encouraging agreement with experiment while reducing the computer time requirements for a given configuration.

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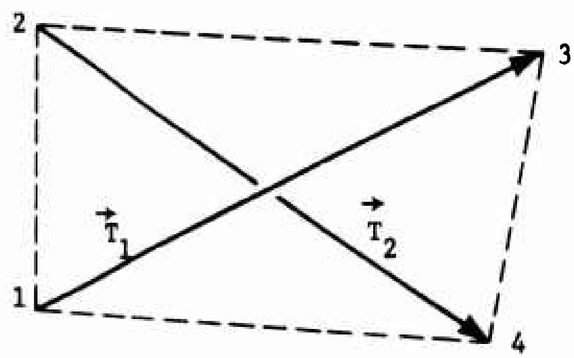
APPENDIX I

PANEL GEOMETRY CALCULATIONS

The analytical procedure presented here follows closely the method first developed in Reference 5. A quadrilateral surface element is described by four corner points, not necessarily lying in the same plane, as shown in the sketch. The quadrilateral element is approximated by a planar panel as follows:



The coordinates in the reference coordinate system are identified by their subscripts. The components of the diagonal vectors $\vec{T}_1$ and $\vec{T}_2$ are

$$t_{1x} = x_3 - x_1 \quad t_{1y} = y_3 - y_1 \quad t_{1z} = z_3 - z_1$$

$$t_{2x} = x_4 - x_2 \quad t_{2y} = y_4 - y_2 \quad t_{2z} = z_4 - z_2$$

We may now obtain a vector $\vec{N}$ (and its components) by taking the cross product of the diagonal vectors.

$$\vec{N} = \vec{t}_2 \times \vec{t}_1$$

$$N_x = t_{2y}t_{1z} - t_{1y}t_{2z}$$

$$N_y = t_{1x}t_{2z} - t_{2x}t_{1z}$$

$$N_z = t_{2x}t_{1y} - t_{1x}t_{2y}$$

The unit normal vector, $\vec{n}$, to the plane of the element is taken as $\vec{N}$ divided by its own length $|\vec{N}|$ (direction cosines of outward unit normal).

$$n_x = \frac{N_x}{N}$$

$$n_y = \frac{N_y}{N}$$

$$n_z = \frac{N_z}{N}$$

where

$$N = [N_x^2 + N_y^2 + N_z^2]^{1/2}$$

The plane of the element is now completely determined if a point in this plane is specified. This point is taken as the point whose coordinates $\bar{x}$, $\bar{y}$, $\bar{z}$ are the average of the coordinates of the four input points.

$$\bar{x} = \frac{1}{4}[x_1 + x_2 + x_3 + x_4]$$

$$\bar{y} = \frac{1}{4}[y_1 + y_2 + y_3 + y_4]$$

$$\bar{z} = \frac{1}{4}[z_1 + z_2 + z_3 + z_4]$$

Now the input points will be projected into the plane of the element along the normal vector. The resulting points are the corner points of the quadrilateral element. The input points are equidistant from the plane, and this distance is

$$d = |n_x(\bar{x} - x_1) + n_y(\bar{y} - y_1) + n_z(\bar{z} - z_1)|$$

The coordinates of the corner points in the reference coordinate system are given by

$$\left.\begin{aligned} x_k' &= x_k + (-1)^{k+1} n_x d \\ y_k' &= y_k + (-1)^{k+1} n_y d \\ z_k' &= z_k + (-1)^{k+1} n_z d \end{aligned}\right\} \quad k = 1, 2, 3, 4$$

Now the element coordinate system must be constructed. This requires the components of three mutually perpendicular unit vectors, one of which points along each of the coordinate axis of the system, and also the coordinates of the origin of the coordinate system. All these quantities must be given in terms of the reference coordinate system. The unit normal vector is taken as one of the unit vectors, so two perpendicular unit vectors in the plane of the element are needed. Denote these unit vectors $\vec{t}_1$ and $\vec{t}_2$. The vector $\vec{t}_1$ is taken as $\vec{T}_1$ divided by its own length T_1, i.e.,

$$t_{1x} = \frac{T_{1x}}{T_1}$$

$$t_{1y} = \frac{T_{1y}}{T_1}$$

$$t_{1z} = \frac{T_{1z}}{T_1}$$

where

$$T_1 = [T_{1x}^2 + T_{1y}^2 + T_{1z}^2]^{1/2}$$

The vector t_2 is defined by $\vec{t}_2 - \vec{n} \times \vec{t}_1$, so that its components are

$$t_{2x} = n_y t_{1z} - n_z t_{1y}$$

$$t_{2y} = n_z t_{1x} - n_x t_{1z}$$

$$t_{2z} = n_x t_{1y} - n_y t_{1x}$$

The vector $\vec{t}_1$ is the unit vector parallel to the x or ξ axis of the element coordinate system, while $\vec{t}_2$ is parallel to the y or η axis, and $\vec{n}$ is parallel to the z of ζ axis of this coordinate system.

To transform the coordinate of points and the components of vector between the reference coordinate system and the element coordinate system, a transformation matrix is required. The elements of this matrix are the three components of the three basic unit vectors $\vec{t}_1$, $\vec{t}_2$, and $\vec{n}$.

$$T = \begin{bmatrix} t_{1x} & t_{1y} & t_{1z} \\ t_{2x} & t_{2y} & t_{2z} \\ n_x & n_y & n_z \end{bmatrix}$$

In the computer program, the elements of this matrix are referred to as follows:

$$a_{11} = t_{1z} \qquad a_{12} = t_{1y} \qquad a_{13} = t_{1z}$$

$$a_{21} = t_{2x} \qquad a_{22} = t_{2y} \qquad a_{23} = t_{2z}$$

$$a_{31} = n_x \qquad a_{32} = n_y \qquad a_{33} = n_z$$

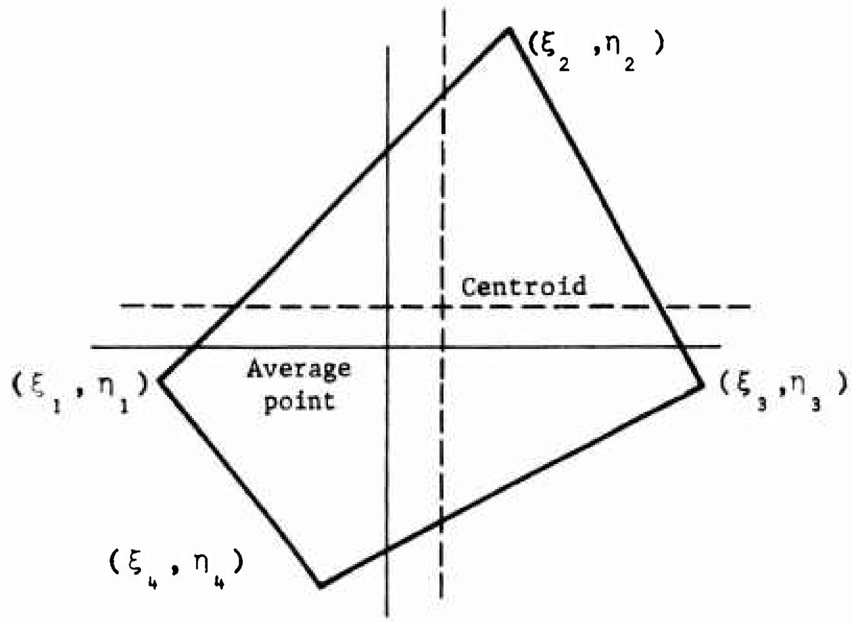
The corner points are now transformed into the element coordinate system based on the average point as origin. These points have coordinates x_k', y_k', z_k' in the reference coordinate system. Their coordinates in the element coordinate system with this origin are denoted by ξ_k, η_k, 0. Because they lie in the plane of the element, they have a zero z or ζ

coordinate in the element coordinate system. Also, because the vector $\vec{t}_1$, which defines the x or ξ axis of the element coordinate system, is a multiple of the "diagonal" vector from point 1 to 3, the coordinate η_1 and the coordinate η_3 are equal. In the (ξ,η) coordinate system, the corner points of the element are:

$$\xi_k = t_{1x}(\bar{x} - x_k') + t_{1y}(\bar{y} - y_k') + t_{1z}(\bar{z} - z_k')$$

$$\eta_k = t_{2x}(\bar{x} - x_k') + t_{2y}(\bar{y} - y_k') + t_{2z}(\bar{z} - z_k')$$

These corner points are taken as the corners of a plane quadrilateral as illustrated in the following sketch.



The origin of the element coordinate system is now transferred to the centroid of the area of the quadrilateral. With the average point as origin the coordinates of the centroid in the element coordinate system are:

$$\xi_0 = \frac{1}{3} \frac{1}{\eta_2 - \eta_4} [\xi_4(\eta_1 - \eta_2) + \xi_2(\eta_4 - \eta_1)]$$

$$\eta_0 = \frac{1}{3}\eta_1$$

These are subtracted from the coordinates of the corner points in the element coordinate system based on the average point as origin to obtain the coordinates of the corner points in the element coordinate system based on the centroid as origin. Accordingly, these latter coordinates are

$$\xi_k = \xi_k - \xi_0 \qquad \qquad k = 1, 2, 3, 4$$

$$\eta_k = \eta_k - \eta_0$$

Since the centroid is to be used as the control point of the element, its coordinates in the reference coordinate system are required. These coordinates are

$$x_0 = \bar{x} + t_{1x}\xi_0 + t_{2x}\eta_0$$

$$y_0 = \bar{y} + t_{1y}\xi_0 + t_{2y}\eta_0$$

$$z_0 = \bar{z} + t_{1z}\xi_0 + t_{2z}\eta_0$$

Finally, the area of the quadrilateral is

$$A = \frac{1}{2}(\xi_3 - \xi_1)(\eta_2 - \eta_4)$$

APPENDIX II

SUBROUTINE DESCRIPTIONS

(arranged in alphabetical order)

This appendix contains a brief outline of the purpose, method, and use of each subroutine. The principal constants and variables in each are listed in the order of their first appearance, and identified as input or output data.

Subroutine ANALOG

Purpose: To transform the panel control point and corner points from the real body to the analog body, as required by Gothert's compressibility rule.

Method: The panel control point is transformed simply by multiplying the y and z coordinates by $B = \sqrt{1-M^2}$. The transformation matrix is then corrected for compressiblity, and new panel corner points determined in the panel reference system. Finally, the area and maximum diagonal of the panel are calculated.

Use: Call ANALOG (BETA, YC, ZC, A, XEI, YEI, F, T)

Input:

BETA	Prandtl-Glauert factor = $\sqrt{1-M^2}$
YC	y coordinate of panel control point
ZC	z coordinate of panel control point
A	Transformation matrix
XEI	z coordinate of panel corner point in panel coordinate system
YEI	y coordinate of panel corner point in panel coordinate system

Output:

YC	Transformed y coordinate of panel control point
ZC	Transformed z coordinate of panel control point
A	Transformed transformation matrix
XEI	Transformed x coordinate of panel corner point in panel coordinate system
YEI	Transformed y coordinate of panel corner point in panel coordinate system
F	Panel area

Subroutine ANALOG(cont'd)

Output:(cont'd)

T	Length of maximum diagonal of panel

Subroutine Called: None

Error Returns: None

Subroutine DRAW3D

Purpose: To plot the object as viewed from the viewpoints.

Method: DRAW3D begins by projecting the object onto the display plane (the "V, W" plane) perpendicular to the vector from the origin to the viewpoint. It also generates the panels needed for symmetry if ISYM is zero. The V, W data are then scaled so that they will be plotted in an area 6.5 inches wide by 9.0 inches high.

The program then creates a new list of the panels to be plotted in the array LL. If the IHIDE parameter is zero, the new list will only have the panels that face the viewpoints, and in addition the subroutine OVRLAP will be called to eliminate any panels that are partially or entirely blocked by some other panel.

Finally, the program loops through the new list (LL) and calls the subroutine PLTPAN to plot the panels.

Use: Call DRAW3D (N, M, VX, VY, VZ, ISYM, IHIDE, IBUG)

N The number of vertices

M The number of panels

VX,VY, VZ The coordinates of the viewpoint

ISYM If zero, the object is symmetric about the XZ plane

IHIDE If zero, the program is to eliminate the hidden surfaces

IBUG If nonzero, the coordinate of the vertices in the display plane will be printed. If IBUG = 1, the list contained in the array LL will be printed along with the corresponding coordinates in the display plane

Input:

In addition to the parameters in the calling sequence, the subroutine DRAW3D uses the data in the common arrays V, W, DIST, and L. These arrays are set up in the program WBPLOT.

Subroutine DRAW3D(cont'd)

Output:

The primary output of DRAW3D is the data in the common arrays V, W, DIST, and LL, which are used by the subroutine OVRLAP and PLTPAN. In addition to this there are the optional IBUG printouts, and label on the plot.

Subroutines Used:

NUMBER	Used to draw numbers on the plot
OVRLAP	Used to eliminate blocked panels
PLOT	Used to control the plotting origin
PLTPAN	Used to draw the panels
SYMBOL	Used to draw symbols on the plot

Limitations: See WBPLOT

Subroutine ELEMEN

Purpose: To calculate the panel control point, corner points, and transformation matrix.

Method: The method is described in Appendix I of this report.

Use: Call ELEMEN (I, X, Y, Z, KUTA, XC, YC, ZC, XE, YE, A)

Input:

I	Panel number (not used)
X	x coordinate of panel in reference coordinate system
Y	y coordinate of panel in reference coordinate system
Z	z coordinate of panel in reference coordinate system
KUTA	Not used

Output:

XC	x coordinate of panel control point (centroid) in reference coordinate system
YC	y coordinate of panel control point (centroid) in reference coordinate system
ZC	z coordinate of panel control point (centroid) in reference coordinate system
XE	x coordinate of panel control point in panel coordinate system
YE	y coordinate of panel corner point in panel coordinate system
A	Transformation matrix (to transform from reference coordinate system to panel coordinate system)

Subroutine Called: None

Error Returns: None

Subroutine FORMOM

Purpose: To calculate the force and moment coefficients on wing and body.

Method: The panel area, control point coordinates, and direction cosines are read from TAPE 13 for each panel in sequence. The normal force, lateral force, axial force, and pitching moments of the panel about the origin of coordinates are calculated, and summed. The total force and moment coefficients acting on the configuration are then obtained by dividing these sums by the reference area. The lift, side force, and drag are obtained by resolving the normal force, lateral force, and axial force coefficients into the wind axis system.

If wing section data is required, the program calculates the spanwise lift and drag distribution on the wing. The forces and moment acting on each panel in a given column are summed, and the section force and moment coefficients are calculated with reference to the area of the column of panels.

The output is summarized in tables giving the input geometrical data, pressure coefficients, panel forces and moment. The integrated force and moment data on the wing sections and the complete configuration are also tabulated.

Use: Call FORMOM, (ALPHA, BETA, MA, NPAN, SECT, COMPT, REFA, REFL, XOO, X25)

Input:

NPAN	Number of panels on the configuration
MA	Mach number
ALPHA	Angle of attack (degrees)
BETA	Angle of yaw (degrees)
SECT	Wing section data parameter
COMPT	Component indicator
REFA	Reference area
REFL	Reference length

Subroutine FORMOM(cont'd)

Input:(cont'd)

XOO	Distance of leading edge of MAC from origin
X25	Distance of quarter chord of MAC from origin
CP	Pressure coefficient
F	Panel area
F1,F2, F3	Direction cosines of normal
XC,YC, ZC	Panel centroid coordinates
DELY	Width of column of panels
XLE	Distance from column leading edge to origin

Output:

DCZ	Panel normal force
DCY	Panel lateral force
DCX	Panel axial force
DCMX	Panel moment about x axis
DCMY	Panel moment about y axis
DCMZ	Panel moment about z axis
CZ	Normal force coefficient
CY	Lateral force coefficient
CX	Axial force coefficient
CL	Lift coefficient
CS	Side force coefficient
CD	Drag coefficient
CMX	Pitching moment about x axis

Subroutine FORMOM(cont'd)

Output(cont'd)

CMY	Pitching moment about y axis
CMZ	Pitching moment about z axis
DXN	Center of pressure location
CM25	Pitching moment about quarter chord of MAC
CM00	Pitching moment about leading edge of MAC

Subroutine Called: None

Error Returns: None

Subroutine INFLU

Purpose: To calculate the three components of velocity induced by a constant source distribution on a given panel.

Method: The method of Hess and Smith (Reference 1) is used. The velocity component formulas are summarized in the Aerodynamic Theory Section of this report.

Use: Call INFLU (I, J, XE, YE, XN, YN, ZN, XC,YC, AC, A, T, F, VX,VY, VZ, SYM).

Input:

I	Control point number
J	Influencing panel number
XE	x coordinate of panel corner point in panel coordinate system
YE	y coordinate of panel corner point in panel coordinate system
XN	x coordinate of control point I in reference coordinate system
YN	y coordinate of control point I in reference coordinate system
ZN	z coordinate of control point I in reference coordinate system
XC	x coordinate of centroid of panel J in reference coordinate system
YC	y coordinate of centroid of panel J in reference coordinate system
ZC	z coordinate of centroid of panel J in reference coordinate system
A	Transformation matrix of panel J
T	Maximum diagonal of panel J
F	Area of panel J

Subroutine INFLU(cont'd)

Input:(cont'd)

SYM — Logical variable denoting symmetry in panels about x, z plane. (SYM is true if the panel and control point lie on the same side of the plane of symmetry; SYM is false otherwise.)

Output:

VX — x component of induced velocity (in reference coordinate system)

VY — y component of induced velocity (in reference coordinate system)

VZ — z component of induced velocity (in reference system)

Subroutine Called: None

Error Returns: Calls EXIT if control point lies on edge of panel.

Subroutine LATICE

Purpose: To calculate the three components of velocity induced by a given vortex lattice.

Method: The method of Rubbert and Saaris (Reference 2) is used. The velocity component formulas are summarized in the Aerodynamic Theory section of this report.

Use: Call LATICE (XG1, YG1, ZG1, XG2, ZG2, GA, N, XP, YP, ZP, U, V, W, SYM, IL)

Note: All points are given in the reference coordinate system

Input:

N	Number of bound vortices in lattice
XG1	x coordinate of inboard end of bound vortex
YG1	y coordinate of inboard end of bound vortex
ZG1	z coordinate of inboard end of bound vortex
XG2	x coordinate of outboard end of bound vortex
YG2	y coordinate of outboard end of bound vortex
ZG2	z coordinate of outboard end of bound vortex
GA	Relative strengths of bound vortices in lattice
XP	x coordinate of control point
YP	y coordinate of control point
ZP	z coordinate of control point
SYM	Symmetry parameter
IL	Vortex Number

Output:

U	x component of induced velocity at control point (in reference coordinate system)
V	y component of induced velocity at control point (in reference coordinate system)

Subroutine LATICE(cont'd)

Output:(cont'd)

W	z component of induced velocity at control point (in reference coordinate system)

Subroutine Called: None

Error Returns: Calls EXIT if control point lies on a vortex line.

Subroutine LINCOF

Purpose: To compute the equation for the given line segment.

Method: The subroutine LINCOF computes the coefficientes in the equation for the given line segment. The equation used is:

$$AV + BW + C = 0$$

Use: Call LINCOF (V_1, W_1, V_2, W_2, A, B, C)

Input:

V_1, W_1 The coordinates of the first point

V_2, W_2 The coordinates of the second point

Output:

A,B,C, The coefficients in the equation

Subroutines Called: None

Error Returns: None

Subroutine OVRLAP

Purpose: To eliminate overlapped panels and overlapped parts of panels.

Method: The subroutine OVRLAP goes through two phases in order to eliminate the hidden lines. The first phase runs through each panel listed in the array LL and tests to see if it overlaps or is overlapped by any of the subsequent panels in the list LL. If one of the panels is completely overlapped, it is eliminated. If one of the panels is partially overlapped by the other, the overlapping panel is placed on a list (L) of such panels associated with the overlapped panel.

The second phase runs through the list, L, of partially overlapping panels, and plots the nonhidden line segments. Once their lines have been plotted the panel is eliminated from the list LL.

Use: Call OVRLAP(NN, LNEXT)

Input:

NN The number of vertices

LNEXT The number of panels in LL

In addition to the parameters in the calling sequence, the subroutine OVRLAP uses the data in the common arrays V, W, DIST, and LL.

Output:

OVRLAP draws all the partially overlapped panels, and also modifies the array LL.

Subroutines Called: LINCOF Used to compute the equation for a line segment

PLOT Used to draw the nonhidden line segments

Error Returns: There are four error stops in the subroutine OVRLAP

Stop 4
Stop 5
Stop 10
Stop 12

Subroutine PLTPAN

Purpose: To draw the panels.

Method: The subroutine PLTPAN has three modes of operation. The first mode (IOP = 0) simply initializes the array IVECT. The second mode (IOP = 2 or 3) enters a sequence of connected line segments into the array IVECT (IOP = 3 for the starting point of the first segment, and IOP = 2 for the subsequent points). The third mode (IOP = 1) loops through the array IVECT and draws the indicated line segments.

Use: Call PLTPAN (L, IOP)

Input:

L	The index of the coordinates of the point in question
IOP	The mode parameter (see above)

The data in the common arrays V and W are used in addition to the variables in the calling sequence

Output:

The output of this routine is the plot

Subroutines Called: PLOT Used to draw the panels

Error Returns: None

Subroutine SLEQW

Purpose: To solve a system of linear equations by direct inversion.

Method: Gaussian algorithm for solution of a system of linear equations with pivoting.

Use: Call SLEQW (A, MM, R, MN, M, N, ILL)

Input:

A	Matrix of coefficients of equations (dimensioned MM x MM in calling program)
R	Right side vector matrix (dimensioned MM x MN in calling program)
MM	Maximum dimensions of A
MN	Maximum number of right side vectors
M	Actual dimensions of A
N	Number of right side vectors

Output:

R	Solution vector

Subroutine Called: None

Error Returns: ILL = -1 if system of equations is ill conditioned

Subroutine SOLVE

Purpose: To solve a system of linear equations by an iterative procedure.

Method: The system of linear equations is solved using the Gauss-Seidel iterative procedure, with direct solution of the vortex lattice partition. The method is described in the section of this report titled, "The Boundary Condition Equations" (see page 9).

Use: Call SOLVE (A, B, X, HA, HB, NS, N, LHA, F, EPS, IW, NIT, TPIO, ITA, ILL, HH)

Input:

A	Row of influence coefficient matrix
B	Right side of boundary condition equation
X	Array of source and vortex strengths (solution input vector)
HA	Vortex lattice influence coefficient matrix
HB	Right side of vortex lattice equations
NS	Number of source panels
N	Number of source panels and vortex lattices (Maximum size of matrix A)
LHA	Maximum dimension of matrix HA
F	Relaxation factor (set equal to unity)
EPS	Solution residual limit
IW	Initial value switch If IW = 1, X(I) = 0 If IW = 0, X(I) obtained from previous solution
NIT	Maximum number of iterations
TPIO	Name of file used for storing matrix A
ITA	Number of x values printed out if ILL = 2. If ITA = 0, all x values are printed.

Subroutine SOLVE(cont'd)

Input:

ILL	=0	No printout
	=1	Small printout (iteration step only)
	=2	Large printout, including complete matrix of influence coefficients
	=3	Same as 2, but without matrix
HH		Auxiliary array

Output:

X	Array of source and vortex strengths (solution output vector)
ITA	Number of iterations
ILL	=0 Normal solution =1 Error return

Subroutine Called: SLEQW

Error Returns: If ILL = 1, subroutine writes error message, and returns. The subroutine calls EXIT if the solution diverges.

Program WBAERO

Purpose: To calculate the pressure coefficients at the panel control points on wings, bodies, and wing-body combinations in subsonic compressible flow.

Method: The panel corner points computed by subroutine WBPAN are read from the auxiliary file TAPE 11. Subroutine ELEMEN is then called for each panel in turn. It calculates the control point, the transformation matrix, and transforms the corner points from the reference coordinate system to the panel coordinate system. The panel control points and corner points are then transformed to the analog body using subroutine ANALOG, in preparation for calculation of the aerodynamic influence coefficients. Subroutine INFLU calculates the three components of velocity induced by the source panels, and subroutine LATICE calculates the three components of velocity induced by each vortex lattice. These velocities are combined to form the matrix of aerodynamic influence coefficients, one row at a time. The influence coefficient matrix is stored on auxiliary file TAPE 10 in row order, and the three components of velocity are stored on TAPE 12, also in row order. The right side of the boundary condition equation is computed for each angle of attack and yaw, and the system of equations solved for the source and vortex strengths by calling subroutine SOLVE. A detailed description of the method is given in the Aerodynamic Theory section of this report. The pressure coefficients are then obtained by summing the products of the velocity components and singularity strengths, and applying equations (26) and (27) given in the Aerodynamic Theory section.

Use: Call OVERLAY (FRWB, 3, 0)

Input:

TEXT	Identifying title
PRINT	Print option selected (see input section)
NIT	Maximum number of iterations
IEPS	Exponent of 10 setting limit on residue of iterative solution
ITYPE	Type of solution procedure selected

Program WBAERO(cont'd)

Input:(cont'd)

ISAVE	Control parameter for reading influence coefficients and velocities components for auxiliary files TAPE 10 and TAPE 12, on to TAPE 11.
SIM	Panel symmetry parameter
KUT	Vortex lattice control parameter
NBV	Number of body vortices having same strength as adjacent wing vortices
NV	Number of wing vortices associated with each body vortex
KOMPR	Compressibility rule parameter
POINTS	Number of field points requested
NORPAN	Number of panels with non-zero normal velocity
NMA	Number of Mach numbers
MA	Mach number
NAL	Number of angles of attack or yaw
ALPHA	Angle of attack
BETA	Angle of yaw
X,Y,Z	Source panel corner points in reference coordinate system
XL,YL, ZL	Vortex panel corner points in reference coordinate system
XP,YP, ZP	Field point coordinates
GA	Relative strengths of bound vortices in vortex lattices

Output:

I	Control point index
IL	Vortex lattice number
J	Panel Number

Program WBAERO(cont'd)

Output:(cont'd)

LP	Bound vortex number
BETA1	Prandtl-Glauert factor
NP	Panel number at which non-zero normal specified
NORVEL	Normal velocity
XC,YC, ZC,XCI, YCI,ZCI	Panel control points in reference coordinate system
XE, YE	Panel control points in reference coordinate system
A	Panel transformation matrix
F	Panel area
T	Maximum diagonal of panel
VX,VY, VZ	Three components of induced velocity in reference coordinate system
AM	Component of velocity, normal to plane of panel (influence coefficient)
RULE 1	Gothert's rule 1 selected
RULE 2	Gothert's rule 2 selected
VXU,VYU VZU	Three components of the free-stream velocity vector
RS	Right side of boundary condition equations
ILL	Matrix solution indicator
SIGMA	Array of source and vortex strengths
VXR,VYR VZR	Resultant velocity component arrays

Program WBAERO(cont'd)

Output:(cont'd)

V	Magnitude of resultant velocity vector
CP	Pressure coefficient array

Subroutines Called: ELEMEN
ANALOG
INFLU
LATIC
SOLVE
FORMOM
EXIT

Error Returns: Program calls EXIT if:

1. MA > 1.0

2. J > 1500

3. LP > 40

4. IL > 35

5. ILL = 1

Program WBOLAY

Purpose: Main overlay for wing-body analysis program

Method: To call the primary overlay programs WBPAN and WBAERO

Use: OVERLAY (FRWB, 0, 0)

FRWB is overlay file name

Program Called:

OVERLAY (FRWB, 1, 0) (WBPAN)

OVERLAY (FRWB, 2, 0) (WBPLOT)

OVERLAY (FRWB, 3, 0) (WBAERO)

Subroutines Called: Exit

Program WBPAN

Purpose: To calculate panel subdivision for wings, bodies, or wing-body combinations.

Method: Several alternate paths are available in this subroutine depending on the values of the control parameters selected. Individual panel corner point arrays are read in if SINGPA = 1, body section data is read in if CASE = 1 or 3, and wing section data is read in if CASE = 2 or 3.

Four options are available for reading in the body section area. If OPT = 0, the y and z coordinates of the panel corner points are required. If OPT = 1, the preceding section corner points are used, and no additional data is read. If OPT = 2, the panel corner points are specified by the polar coordinates r and θ. For bodies of revolution having uniform panel spacing, OPT = 3 provides a simplified input option, and requires the input of only the radius and θ increment for each section. If OPT = 0 or 2 have been selected, the x coordinate of the panel corner points may be shifted out of the plane of the section by an amount Δx to allow more freedom in paneling intersections. In all cases, the program calculates the x,y,z coordinates of the four panel corners in the reference coordinate system, and writes them on the auxiliary file TAPE 11 and the output file.

The wing section data is input as airfoil coordinate arrays. These arrays may be given in the reference coordinate system, or in terms of the local percent chord. If the latter option is selected, the chord length, twist angle, and twist center must be specified for each section. An arbitrary dihedral angle may also be specified for each section.

The internal vortex lattice panels are located on the mean camber line of the wing section. The relative strength (GAMMA) array must be specified for each section. In addition, the y coordinate of panel corner points may be shifted out of the plane of the section by an amount Δy to allow more freedom in paneling wing tips and wing-body intersections. In all cases, the program calculates the x,y,z coordinates of the four corners of the surface panels and vortex lattice panels in the reference coordinate system, and writes them on the auxiliary file TAPE 11 and the output file. For wing-body combinations (CASE = 3) additional vortex lattice panels may be specified inside the body. The input required is similar to that described above

Program WBPAN(cont'd)

Method:(cont'd)

the wing panels. The program calculates the x,y,z coordinates of the four corners of the additional vortex panels in the reference coordinate system, and writes them on the auxiliary file TAPE 11 and the output file.

Use: Call OVERLAY (FRWB, 1, 0)

Input:

TEXT	Identifying title
CASE	Component identification parameter
PLOT	Plot selection parameter
SIM	Configuration symmetry parameter
ISAVE	Save tape parameter
PRINT	Print option
SINGPA	Single panel selection parameter
NOPAN	Number of panels to be deleted
XX,YY, ZZ	Panel corner point coordinate in reference coordinate system
NB	Number of body sections
NW	Number of wing sections
NV	Number of vortex lattices in body
XBE,YBE ZBE	Section coordinates in reference coordinate system
MB,NW	Number of panel corner points in wing or body section
MV	Number of vortex panels in body vortex lattices
OPT	Corner point input option (see description above)
CHD	Panel chord

Program WBPAN(cont'd)

Input:(cont'd)

ALF	Panel twist angle(degrees)
XAL	Twist reference point
KOORD	Wing panel coordinate system parameter
FLAG	Branch point indicator(required to change number of panels from section to section)
DEL	Dihedral parameter
DELTA	Wing section dihedral (degrees)
YO,ZO	Coordinate of axis of rotation for dihedral
THET	Theta increment (degrees) for OPT = 3
A	-z coordinate of body panel corner point if OPT = 0 and CASE = 1
	-r coordinate of body panel corner point if OPT > 0 and CASE = 1
	-z coordinate of wing panel corner point if CASE = 2
B	-y coordinate of body panel corner point if OPT = 0 and CASE = 1
	-θ coordinate (in degrees) of body panel corner point if OPT > 0 and CASE = 1
	-x coordinate of wing panel corner point if CASE = 2
C	-Relative strength of vortex lattice panels (GAMMA)
D	-Δx shift of body panel corner point if CASE = 1
	-Δy shift of wing panel corner point if CASE = 2
WAKE	Length of vortex lattice in wake in percent of local chord

Program WBPAN(cont'd)

Input:(cont'd)

POINT	Location of vortex lattice control point behind trailing edge in percent of local chord
XLP,YH, ZLP	Coordinates of terminal points of streamwise vortices (input only if FLAG = 3 and CASE > 2)

Output:

PANEL	Panel number
NPAN	Panel numbers of panels to be deleted
XX,YY ZZ,X,Y Z	Panel corner point coordinates in reference coordinate system
XH,YH, ZH,XC, YC,ZC	Vortex lattice panel coordinates in reference coordinate system
MINUS 1	End of record mark for TAPE 11

Subroutine Called: EXIT

Error Returns: Program calls EXIT if:

1. NB > 70
2. MB > 60
3. NW > 40
4. NW > 60
5. NV > 40
6. MV > 60

Program WBPLOT

Purpose: To plot the panel geometry

Method: The plot parameters and viewpoint coordinates are read from the input file, and the panel corner point coordinates are read from TAPE 11. The data is stored in labelled COMMONS SCRAT, PLODAT, and PLOPAR prior to calling the plot subroutines.

Use: Call OVERLAY (FRWB, 2,0)

Input:

NVU	Number of viewpoints
IPRINT	Print parameter
IHIDE	Hidden line parameter
IBUG	Debug print parameter
VUE	Viewpoint coordinate
X,Y,Z	Panel corner point coordinates

Output:

M	Number of panels
N	Number of corner points
L	Array of corner point indices

Subroutines Called:

PLOTS

FACTOR

DRAW3D

PLOT

Error Returns:

1. NVU > 4 - Subroutine writes error message & returns
2. M > 1500 - Subroutine writes error message & returns
3. N > 3000 - Subroutine writes error message & returns

APPENDIX III

SAMPLE INPUT

The input for a wing-body-tail configuration is given in this appendix. Figure 28 is a computer generated plot of the paneling used for this configuration. Panels are input for one side of the configuration only.

The body is an ogive cylinder with a blunt base, and is subdivided into 72 panels, including base panels. The wing has a truncated delta platform and a thickness/chord ratio of approximately 15 percent. It is subdivided into 69 panels. The vertical tail has a swept constant chord planform and the same airfoil section as the wing. It contains an additional 32 panels. The total number of source panels on the configuration is 168.

Vortex lattice panels are automatically included inside the wing, while the vortex lattices inside the vertical tail are input as body vortices. Eight vortex lattices are used in the wing, body, and vertical tail.

The sample input is chosen to illustrate some of the special features of the program. These features are described below:

1. Plot Option - The plot option is selected by setting PLOT = 1 on Card 2. The plot parameters are set on Cards 9 and 10.

2. Body Input - A simplified body input definition is obtained by setting OPT = 3 on Card 4B. This option only applies to bodies of revolution.

3. Wing and Tail Input - The wing input card set includes the vertical tail. The main wing uses the standard input option, while the vertical tail is defined in a horizontal plane and rotated into the vertical position using the dihedral option (DEL = 1 on Card 5B). Since the wing and tail have the same airfoil section, this data is input only for the first wing section, and the remainder are defined by setting OPT = 1 on Card 5B. The vortex lattices are automatically calculated for the main wing, but omitted from the vertical tail by setting FLAG = 2. The vertical tail vortex lattices are input later as body vortices. The trailing vortices from the wing vortex lattice are extended 100 units into the wake using Card Set 7, and setting FLAG = 3 on Card 5B. The vortex lattice control points are defined by Card 6.

4. Body Vortices - A vortex lattice is input inside the body to provide a mechanism for carry-over of lift. The strengths and locations of the bound vortices in this lattice are chosen to match those of the adjacent wing vortices in this lattice, and the trailing vortex is extended into the wake such that it terminates at the same location as the inboard wing trailing vortices.

   Body vortices are also input inside the vertical tail. The bound vortices are located in the plane of symmetry under the spanwise panel edges, and given a strength proportional to the airfoil local thickness distribution. The trailing vortices are extended 100 units into the wake, using Card Set 8D-1. The vertical tail vortex lattice control panels are defined by setting OPT = 2 on Card 8B, and reading in the control point coordinates on Card 8D-2 and 3. Finally, the symmetry option is ignored for these vortex lattices by setting SIMOPT = 1 on Card 8B. This suppresses the image vortex lattice system which in this case would exactly cancel the defined vortex lattice system in the vertical tail and result in a singular matrix being generated in the aerodynamic section of the program.

5. Field Point Option - The field point option is selected by setting POINTS = 16 on Card 16. The coordinates of the 16 field points follow on Card Set 16A.

6. Normal Velocity Option - The normal velocity option is selected by setting NORPAN = 8 on Card 16. The indices of the 8 points are identified on Card Set 16B. In this example, NORVEL = 0, so the normal component of the onset velocity is set equal to zero on the blunt base of the body.

```
       WING-BODY-TAIL TEST CASE
         3          1          1

        10          1
0.                                          5          1
45.         0.
1.5                                         5          3
45.         .40622
4.5                                         5          3
45.         1.04487
7.5                                         5          3
45.         1.4573
10.5                                        5          3
45.         1.6503
12.0                                        5          3
45.         1.6667
14.0                                        5          3
45.         1.6667
16.0                                        5          3
45.         1.6667
20.0                                        5          3
45.         1.6667
20.0                                        5          3
45.         0.
           6          1
12.0        1.667       0.          4.0         0.          0.             17    0    3
100.        0.
90.         -.950       0.
70.         -4.113
50.         -5.810
30.         -7.319
10.         -6.842
5.          -3.504
1.25        -1.842
0.          0.          0.          0.
1.25        1.842       1.842       0.
5.          3.504       3.504       0.
10.         4.842       4.842       0.
30.         7.319       7.319       0.
50.         6.910       6.810       0.
70.         4.113       4.113       0.
90.         .950        .950        0.
100.        0.          0.          0.
13.43       3.5         0.          2.57        0.0         0.0            17    1    3
15.0        5.5         0.          1.0         0.          0.             17    1    1
16.         0.          1.667       4.0         0.          0.             17    1    2    1
90.         0.          1.667
17.5        1.0         1.667       4.0         0.          0.             17    1    2    1
90.         0.          1.667
19.         2.0         1.667       4.0         0.          0.             17    1    2    1
90.         0.          1.667
100.        1.0
100.        1.667       0.
100.        3.5         0.
100.        3.5         0.
100.        5.5         0.
           5
12.         0.          0.                      9
0.          0.
.05         0.          1.842
.20         0.          3.504
.40         0.          4.842
```

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```
1.20        0.          7.319
2.0         0.          6.810
2.8         0.          4.113
3.60        0.          .950
4.00        0.          0.
100.        0.
101.        0.
12.         1.667       0.                  9         1         1
16.         0.          1.667               9         0         2         1
0.          0.          0.
.05         0.          1.842
.20         0.          3.504
.40         0.          4.842
1.20        0.          7.319
2.0         0.          6.81
2.8         0.          4.113
3.6         0.          .95
4.0         0.          0.
100.        0.          0.
4.00        0.          0.
4.08        0.          0.
17.5        0.          2.667               9         1         2         1
19.0        0.          3.667               9         1         1         1
          -1          1
-50000.   50000.    20000.
       AERODYNAMIC CALCULATIONS
          15          -4          2

          -1          1           2
           2         16           8
1.0         .09575      .23115
18.         .58927      -1.42263
15.90498    4.35340     .00903
15.90498    4.35340     -.00903
12.         2.          .05
13.         2.          .05
14.         2.          .05
15.         2.          .05
16.         2.          .05
17.         2.          .05
12.         2.          -.05
13.         2.          -.05
14.         2.          -.05
15.         2.          -.05
16.         2.          -.05
17.         2.          -.05
         65
         66
         67
         68
         69
         70
         71
         72
          1
0.
          2
0.
0.          10.
  122CARDS WERE READ
```

APPENDIX IV

SAMPLE OUTPUT

The output for a wing-body-tail configuration is given in this appendix. Only standard output is given, since the print option PRINT = 0 was selected.

1. List of Input Data - The program lists all input data.

2. Panel Corner Point Coordinates - The corner point coordinates of the body panels, wing panels, and vortex panels are listed.

3. Aerodynamic Parameters - Selected aerodynamic parameters are listed, together with the CPU time required to calculate the aerodynamic matrix and solve the system of equations.

4. Solution Parameters and Singularity Strengths - A list giving the residuals obtained after each step of the iteration procedure is printed, together with the final array of singularity strengths obtained, in order of panel number.

5. Velocity and Pressure Distribution - The three components of velocity, the magnitude of the velocity vector, and the pressure coefficient are tabulated for each panel, together with the location of the panel control point.

6. Total Coefficients - The axial, normal, and side forces, the moments about the three coordinate axes, the pitching moment about the reference point and the quarter chord of the MAC, the center of pressure, and the lift and drag coefficients are listed.

Items 4, 5, and 6 are repeated for each angle of attack or yaw selected.

WING-BODY-TAIL TEST CASE

INPUT OF BODY CONTOUR

NO. OF SECTIONS= 10
COORD= 0

BODY PANEL CORNER POINT COORDINATES

PANEL	X_1	Y_1	Z_1	X_2	Y_2	Z_2	X_3	Y_3	Z_3	X_4	Y_4	Z_4
1	0.000	0.000	0.000	0.000	0.000	0.000	1.500	.287	.287	1.500	0.000	.406
2	0.000	0.000	0.000	0.000	0.000	0.000	1.500	.406	.000	1.500	.287	.287
3	0.000	0.000	0.000	0.000	0.000	0.000	1.500	.287	-.287	1.500	.406	.000
4	0.000	0.000	0.000	0.000	0.000	0.000	1.500	.000	-.406	1.500	.287	-.287
5	0.000	-0.000	0.000	0.000	-0.000	0.000	1.500	-.287	-.287	1.500	-.000	-.406
6	0.000	-0.000	0.000	0.000	-0.000	0.000	1.500	-.406	.000	1.500	-.287	-.287
7	0.000	-0.000	0.000	0.000	-0.000	0.000	1.500	-.287	.287	1.500	-.406	.000
8	0.000	-0.000	0.000	0.000	-0.000	0.000	1.500	-0.000	.406	1.500	-.287	.287
9	1.500	0.000	.406	1.500	.287	.287	4.500	.739	.739	4.500	0.000	1.045
10	1.500	.287	.287	1.500	.406	.000	4.500	1.045	.000	4.500	.739	.739
11	1.500	.406	.000	1.500	.287	-.287	4.500	.739	-.739	4.500	1.045	.000
12	1.500	.287	-.287	1.500	.000	-.406	4.500	.000	-1.045	4.500	.739	-.739
13	1.500	-.000	-.406	1.500	-.287	-.287	4.500	-.739	-.739	4.500	-.000	-1.045
14	1.500	-.287	-.287	1.500	-.406	.000	4.500	-1.045	.000	4.500	-.739	-.739
15	1.500	-.406	.000	1.500	-.287	.287	4.500	-.739	.739	4.500	-1.045	.000
16	1.500	-.287	.287	1.500	-0.000	.406	4.500	-0.000	1.045	4.500	-.739	.739
17	4.500	0.000	1.045	4.500	.739	.739	7.500	1.030	1.030	7.500	0.000	1.457
18	4.500	.739	.739	4.500	1.045	.000	7.500	1.457	.000	7.500	1.030	1.030
19	4.500	1.045	.000	4.500	.739	-.739	7.500	1.030	-1.030	7.500	1.457	.000
20	4.500	.739	-.739	4.500	.000	-1.045	7.500	.000	-1.457	7.500	1.030	-1.030
21	4.500	-.000	-1.045	4.500	-.739	-.739	7.500	-1.030	-1.030	7.500	-.000	-1.457
22	4.500	-.739	-.739	4.500	-1.045	.000	7.500	-1.457	.000	7.500	-1.030	-1.030
23	4.500	-1.045	.000	4.500	-.739	.739	7.500	-1.030	1.030	7.500	-1.457	.000
24	4.500	-.739	.739	4.500	-0.000	1.045	7.500	-0.000	1.457	7.500	-1.030	1.030
25	7.500	0.000	1.457	7.500	1.030	1.030	10.500	1.167	1.167	10.500	0.000	1.650
26	7.500	1.030	1.030	7.500	1.457	.000	10.500	1.650	.000	10.500	1.167	1.167
27	7.500	1.457	.000	7.500	1.030	-1.030	10.500	1.167	-1.167	10.500	1.650	.000
28	7.500	1.030	-1.030	7.500	.000	-1.457	10.500	.000	-1.650	10.500	1.167	-1.167
29	7.500	-.000	-1.457	7.500	-1.030	-1.030	10.500	-1.167	-1.167	10.500	-.000	-1.650
30	7.500	-1.030	-1.030	7.500	-1.457	.000	10.500	-1.650	.000	10.500	-1.167	-1.167
31	7.500	-1.457	.000	7.500	-1.030	1.030	10.500	-1.167	1.167	10.500	-1.650	.000
32	7.500	-1.030	1.030	7.500	-0.000	1.457	10.500	-0.000	1.650	10.500	-1.167	1.167
33	10.500	0.000	1.650	10.500	1.167	1.167	12.000	1.179	1.179	12.000	0.000	1.667
34	10.500	1.167	1.167	10.500	1.650	.000	12.000	1.667	.000	12.000	1.179	1.179
35	10.500	1.650	.000	10.500	1.167	-1.167	12.000	1.179	-1.179	12.000	1.667	.000
36	10.500	1.167	-1.167	10.500	.000	-1.650	12.000	.000	-1.667	12.000	1.179	-1.179
37	10.500	-.000	-1.650	10.500	-1.167	-1.167	12.000	-1.179	-1.179	12.000	-.000	-1.667
38	10.500	-1.167	-1.167	10.500	-1.650	.000	12.000	-1.667	.000	12.000	-1.179	-1.179
39	10.500	-1.650	.000	10.500	-1.167	1.167	12.000	-1.179	1.179	12.000	-1.667	.000
40	10.500	-1.167	1.167	10.500	-0.000	1.650	12.000	-0.000	1.667	12.000	-1.179	1.179
41	12.000	0.000	1.667	12.000	1.179	1.179	14.000	1.179	1.179	14.000	0.000	1.667

42	12.000	1.179	1.179	12.000	1.667	.000	14.000	1.667	.000	14.000	1.179	1.179
43	12.000	1.667	.000	12.000	1.179	-1.179	14.000	1.179	1.179	14.000	1.667	.000
44	12.000	1.179	-1.179	12.000	.000	-1.667	14.000	.000	-1.667	14.000	1.179	-1.179
45	12.000	-.000	-1.667	12.000	-1.179	-1.179	14.000	-1.179	-1.179	14.000	-.000	-1.667
46	12.000	-1.179	-1.179	12.000	-1.667	.000	14.000	-1.667	.000	14.000	-1.179	-1.179
47	12.000	-1.667	.000	12.000	-1.179	1.179	14.000	-1.179	1.179	14.000	-1.667	.000
48	12.000	-1.179	1.179	12.000	-0.000	1.667	14.000	-0.000	1.667	14.000	-1.179	1.179
49	14.000	0.000	1.667	14.000	1.179	1.179	16.000	1.179	1.179	16.000	0.000	1.667
50	14.000	1.179	1.179	14.000	1.667	.000	16.000	1.667	.000	16.000	1.179	1.179
51	14.000	1.667	.000	14.000	1.179	-1.179	16.000	1.179	-1.179	16.000	1.667	.000
52	14.000	1.179	-1.179	14.000	.000	-1.667	16.000	.000	-1.667	16.000	1.179	-1.179
53	14.000	-.000	-1.667	14.000	-1.179	-1.179	16.000	-1.179	-1.179	16.000	-.000	-1.667
54	14.000	-1.179	-1.179	14.000	-1.667	.000	16.000	-1.667	.000	16.000	-1.179	-1.179
55	14.000	-1.667	.000	14.000	-1.179	1.179	16.000	-1.179	1.179	16.000	-1.667	.000
56	14.000	-1.179	1.179	14.000	-0.000	1.667	16.000	-0.000	1.667	16.000	-1.179	1.179
57	16.000	0.000	1.667	16.000	1.179	1.179	20.000	1.179	1.179	20.000	0.000	1.667
58	16.000	1.179	1.179	16.000	1.667	.000	20.000	1.667	.000	20.000	1.179	1.179
59	16.000	1.667	.000	16.000	1.179	-1.179	20.000	1.179	-1.179	20.000	1.667	.000
60	16.000	1.179	-1.179	16.000	.000	-1.667	20.000	.000	-1.667	20.000	1.179	-1.179
61	16.000	-.000	-1.667	16.000	-1.179	-1.179	20.000	-1.179	-1.179	20.000	-.000	-1.667
62	16.000	-1.179	-1.179	16.000	-1.667	.000	20.000	-1.667	.000	20.000	-1.179	-1.179
63	16.000	-1.667	.000	16.000	-1.179	1.179	20.000	-1.179	1.179	20.000	-1.667	.000
64	16.000	-1.179	1.179	16.000	-0.000	1.667	20.000	-0.000	1.667	20.000	-1.179	1.179
65	20.000	0.000	1.667	20.000	1.179	1.179	20.000	0.000	0.000	20.000	0.000	0.000
66	20.000	1.179	1.179	20.000	1.667	.000	20.000	0.000	0.000	20.000	0.000	0.000
67	20.000	1.667	.000	20.000	1.179	-1.179	20.000	0.000	0.000	20.000	0.000	0.000
68	20.000	1.179	-1.179	20.000	.000	-1.667	20.000	0.000	0.000	20.000	0.000	0.000
69	20.000	-.000	-1.667	20.000	-1.179	-1.179	20.000	-0.000	0.000	20.000	-0.000	0.000
70	20.000	-1.179	-1.179	20.000	-1.667	.000	20.000	-0.000	0.000	20.000	-0.000	0.000
71	20.000	-1.667	.000	20.000	-1.179	1.179	20.000	-0.000	0.000	20.000	-0.000	0.000
72	20.000	-1.179	1.179	20.000	-0.000	1.667	20.000	-0.000	0.000	20.000	-0.000	0.000

INPUT OF WING CONTOUR

NO. OF SECTIONS= 6
COORD= 1

WING PANELING

(OUTER SURFACE)
WING PANEL CORNER POINT COORDINATES

PANEL	X_1	Y_1	Z_1	X_2	Y_2	Z_2	X_3	Y_3	Z_3	X_4	Y_4	Z_4
73	16.000	1.667	0.000	16.000	3.500	0.000	15.743	3.500	-.024	15.600	1.667	-.038
74	15.600	1.667	-.038	15.743	3.500	-.024	15.229	3.500	-.106	14.800	1.667	-.165
75	14.800	1.667	-.165	15.229	3.500	-.106	14.715	3.500	-.175	14.000	1.667	-.272
76	14.000	1.667	-.272	14.715	3.500	-.175	14.201	3.500	-.188	13.200	1.667	-.293
77	13.200	1.667	-.293	14.201	3.500	-.188	13.687	3.500	-.124	12.400	1.667	-.194
78	12.400	1.667	-.194	13.687	3.500	-.124	13.558	3.500	-.090	12.200	1.667	-.140
79	12.200	1.667	-.140	13.558	3.500	-.090	13.462	3.500	-.047	12.050	1.667	-.074
80	12.050	1.667	-.074	13.462	3.500	-.047	13.430	3.500	0.000	12.000	1.667	0.000
81	12.000	1.667	0.000	13.430	3.500	0.000	13.462	3.500	.047	12.050	1.667	.074
82	12.050	1.667	.074	13.462	3.500	.047	13.558	3.500	.090	12.200	1.667	.140
83	12.200	1.667	.140	13.558	3.500	.090	13.687	3.500	.124	12.400	1.667	.194
84	12.400	1.667	.194	13.687	3.500	.124	14.201	3.500	.188	13.200	1.667	.293
85	13.200	1.667	.293	14.201	3.500	.188	14.715	3.500	.175	14.000	1.667	.272
86	14.000	1.667	.272	14.715	3.500	.175	15.229	3.500	.106	14.800	1.667	.165
87	14.800	1.667	.165	15.229	3.500	.106	15.743	3.500	.024	15.600	1.667	.038
88	15.600	1.667	.038	15.743	3.500	.024	16.000	3.500	0.000	16.000	1.667	0.000
89	15.600	-1.667	.038	16.000	-1.667	0.000	16.000	-3.500	0.000	15.743	-3.500	.024
90	14.800	-1.667	.165	15.600	-1.667	.038	15.743	-3.500	.024	15.229	-3.500	.106
91	14.000	-1.667	.272	14.800	-1.667	.165	15.229	-3.500	.106	14.715	-3.500	.175
92	13.200	-1.667	.293	14.000	-1.667	.272	14.715	-3.500	.175	14.201	-3.500	.188
93	12.400	-1.667	.194	13.200	-1.667	.293	14.201	-3.500	.188	13.687	-3.500	.124
94	12.200	-1.667	.140	12.400	-1.667	.194	13.687	-3.500	.124	13.558	-3.500	.090
95	12.050	-1.667	.074	12.200	-1.667	.140	13.558	-3.500	.090	13.462	-3.500	.047
96	12.000	-1.667	0.000	12.050	-1.667	.074	13.462	-3.500	.047	13.430	-3.500	0.000
97	12.050	-1.667	-.074	12.000	-1.667	0.000	13.430	-3.500	0.000	13.462	-3.500	-.047
98	12.200	-1.667	-.140	12.050	-1.667	-.074	13.462	-3.500	-.047	13.558	-3.500	-.090
99	12.400	-1.667	-.194	12.200	-1.667	-.140	13.558	-3.500	-.090	13.687	-3.500	-.124
100	13.200	-1.667	-.293	12.400	-1.667	-.194	13.687	-3.500	-.124	14.201	-3.500	-.188
101	14.000	-1.667	-.272	13.200	-1.667	-.293	14.201	-3.500	-.188	14.715	-3.500	-.175
102	14.800	-1.667	-.165	14.000	-1.667	-.272	14.715	-3.500	-.175	15.229	-3.500	-.106
103	15.600	-1.667	-.038	14.800	-1.667	-.165	15.229	-3.500	-.106	15.743	-3.500	-.024
104	16.000	-1.667	0.000	15.600	-1.667	-.038	15.743	-3.500	-.024	16.000	-3.500	0.000
105	16.000	3.500	0.000	16.000	5.500	0.000	15.900	5.500	-.009	15.743	3.500	-.024
106	15.743	3.500	-.024	15.900	5.500	-.009	15.700	5.500	-.041	15.229	3.500	-.106
107	15.229	3.500	-.106	15.700	5.500	-.041	15.500	5.500	-.068	14.715	3.500	-.175
108	14.715	3.500	-.175	15.500	5.500	-.068	15.300	5.500	-.073	14.201	3.500	-.188
109	14.201	3.500	-.188	15.300	5.500	-.073	15.100	5.500	-.048	13.687	3.500	-.124
110	13.687	3.500	-.124	15.100	5.500	-.048	15.050	5.500	-.035	13.558	3.500	-.090
111	13.558	3.500	-.090	15.050	5.500	-.035	15.012	5.500	-.018	13.462	3.500	-.047
112	13.462	3.500	-.047	15.012	5.500	-.018	15.000	5.500	0.000	13.430	3.500	0.000
113	13.430	3.500	0.000	15.000	5.500	0.000	15.012	5.500	.018	13.462	3.500	.047

114	13.462	3.500	.047	15.012	5.500	.018	15.050	5.500	.035	13.558	3.500	.090
115	13.558	3.500	.090	15.050	5.500	.035	15.100	5.500	.048	13.687	3.500	.124
116	13.687	3.500	.124	15.100	5.500	.048	15.300	5.500	.073	14.201	3.500	.188
117	14.201	3.500	.188	15.300	5.500	.073	15.500	5.500	.068	14.715	3.500	.175
118	14.715	3.500	.175	15.500	5.500	.068	15.700	5.500	.041	15.229	3.500	.106
119	15.229	3.500	.106	15.700	5.500	.041	15.900	5.500	.009	15.743	3.500	.024
120	15.743	3.500	.024	15.900	5.500	.009	16.000	5.500	0.000	16.000	3.500	0.000
121	15.743	-3.500	.024	16.000	-3.500	0.000	16.000	-5.500	0.000	15.900	-5.500	.009
122	15.229	-3.500	.106	15.743	-3.500	.024	15.900	-5.500	.009	15.700	-5.500	.041
123	14.715	-3.500	.175	15.229	-3.500	.106	15.700	-5.500	.041	15.500	-5.500	.068
124	14.201	-3.500	.188	14.715	-3.500	.175	15.500	-5.500	.068	15.300	-5.500	.073
125	13.687	-3.500	.124	14.201	-3.500	.188	15.300	-5.500	.073	15.100	-5.500	.048
126	13.558	-3.500	.090	13.687	-3.500	.124	15.100	-5.500	.048	15.050	-5.500	.035
127	13.462	-3.500	.047	13.558	-3.500	.090	15.050	-5.500	.035	15.012	-5.500	.018
128	13.430	-3.500	0.000	13.462	-3.500	.047	15.012	-5.500	.018	15.000	-5.500	0.000
129	13.462	-3.500	-.047	13.430	-3.500	0.000	15.000	-5.500	0.000	15.012	-5.500	-.018
130	13.558	-3.500	-.090	13.462	-3.500	-.047	15.012	-5.500	-.018	15.050	-5.500	-.035
131	13.687	-3.500	-.124	13.558	-3.500	-.090	15.050	-5.500	-.035	15.100	-5.500	-.048
132	14.201	-3.500	-.188	13.687	-3.500	-.124	15.100	-5.500	-.048	15.300	-5.500	-.073
133	14.715	-3.500	-.175	14.201	-3.500	-.188	15.300	-5.500	-.073	15.500	-5.500	-.068
134	15.229	-3.500	-.106	14.715	-3.500	-.175	15.500	-5.500	-.068	15.700	-5.500	-.041
135	15.743	-3.500	-.024	15.229	-3.500	-.106	15.700	-5.500	-.041	15.900	-5.500	-.009
136	16.000	-3.500	0.000	15.743	-3.500	-.024	15.900	-5.500	-.009	16.000	-5.500	0.000
137	20.000	0.000	1.667	21.500	.000	2.667	21.100	.038	2.667	19.600	.038	1.667
138	19.600	.038	1.667	21.100	.038	2.667	20.300	.165	2.667	18.800	.165	1.667
139	18.800	.165	1.667	20.300	.165	2.667	19.500	.272	2.667	18.000	.272	1.667
140	18.000	.272	1.667	19.500	.272	2.667	18.700	.293	2.667	17.200	.293	1.667
141	17.200	.293	1.667	18.700	.293	2.667	17.900	.194	2.667	16.400	.194	1.667
142	16.400	.194	1.667	17.900	.194	2.667	17.700	.140	2.667	16.200	.140	1.667
143	16.200	.140	1.667	17.700	.140	2.667	17.550	.074	2.667	16.050	.074	1.667
144	16.050	.074	1.667	17.550	.074	2.667	17.500	.000	2.667	16.000	0.000	1.667
145	16.000	0.000	1.667	17.500	.000	2.667	17.550	-.074	2.667	16.050	-.074	1.667
146	16.050	-.074	1.667	17.550	-.074	2.667	17.700	-.140	2.667	16.200	-.140	1.667
147	16.200	-.140	1.667	17.700	-.140	2.667	17.900	-.194	2.667	16.400	-.194	1.667
148	16.400	-.194	1.667	17.900	-.194	2.667	18.700	-.293	2.667	17.200	-.293	1.667
149	17.200	-.293	1.667	18.700	-.293	2.667	19.500	-.272	2.667	18.000	-.272	1.667
150	18.000	-.272	1.667	19.500	-.272	2.667	20.300	-.165	2.667	18.800	-.165	1.667
151	18.800	-.165	1.667	20.300	-.165	2.667	21.100	-.038	2.667	19.600	-.038	1.667
152	19.600	-.038	1.667	21.100	-.038	2.667	21.500	.000	2.667	20.000	0.000	1.667
153	21.500	.000	2.667	23.000	.000	3.667	22.600	.038	3.667	21.100	.038	2.667
154	21.100	.038	2.667	22.600	.038	3.667	21.800	.165	3.667	20.300	.165	2.667
155	20.300	.165	2.667	21.800	.165	3.667	21.000	.272	3.667	19.500	.272	2.667
156	19.500	.272	2.667	21.000	.272	3.667	20.200	.293	3.667	18.700	.293	2.667
157	18.700	.293	2.667	20.200	.293	3.667	19.400	.194	3.667	17.900	.194	2.667
158	17.900	.194	2.667	19.400	.194	3.667	19.200	.140	3.667	17.700	.140	2.667
159	17.700	.140	2.667	19.200	.140	3.667	19.050	.074	3.667	17.550	.074	2.667
160	17.550	.074	2.667	19.050	.074	3.667	19.000	.000	3.667	17.500	.000	2.667
161	17.500	.000	2.667	19.000	.000	3.667	19.050	-.074	3.667	17.550	-.074	2.667
162	17.550	-.074	2.667	19.050	-.074	3.667	19.200	-.140	3.667	17.700	-.140	2.667
163	17.700	-.140	2.667	19.200	-.140	3.667	19.400	-.194	3.667	17.900	-.194	2.667
164	17.900	-.194	2.667	19.400	-.194	3.667	20.200	-.293	3.667	18.700	-.293	2.667
165	18.700	-.293	2.667	20.200	-.293	3.667	21.000	-.272	3.667	19.500	-.272	2.667
166	19.500	-.272	2.667	21.000	-.272	3.667	21.800	-.165	3.667	20.300	-.165	2.667
167	20.300	-.165	2.667	21.800	-.165	3.667	22.600	-.038	3.667	21.100	-.038	2.667
168	21.100	-.038	2.667	22.600	-.038	3.667	23.000	.000	3.667	21.500	.000	2.667

WING PANELING

(CAMBER SURFACE)

VORTEX LATTICE CONTROL PANEL CORNER POINT COORDINATES

PANEL	X_1	Y_1	Z_1	X_2	Y_2	Z_2	X_3	Y_3	Z_3	X_4	Y_4	Z_4
169	16.000	1.667	0.000	16.000	3.500	0.000	16.051	3.500	0.000	16.080	1.667	0.000
170	16.000	-3.500	0.000	16.000	-1.667	0.000	16.080	-1.667	0.000	16.051	-3.500	0.000
171	16.000	3.500	0.000	16.000	5.500	0.000	16.020	5.500	0.000	16.051	3.500	0.000
172	16.000	-5.500	0.000	16.000	-3.500	0.000	16.051	-3.500	0.000	16.020	-5.500	0.000

INPUT OF BODY VORTEX SYSTEM

NO. OF BODY VORTICES= 5

BODY PANELING

(CAMBER SURFACE)
VORTEX PANEL CORNER POINT COORDINATES

PANEL	X_1	Y_1	Z_1	X_2	Y_2	Z_2	X_3	Y_3	Z_3	X_4	Y_4	Z_4
173	112.000	0.000	0.000	112.000	1.667	0.000	113.000	1.667	0.000	113.000	0.000	0.000
174	112.000	-1.667	0.000	112.000	-0.000	0.000	113.000	-0.000	0.000	113.000	-1.667	0.000
175	20.000	0.000	1.667	21.500	0.000	2.667	21.580	0.000	2.667	20.080	0.000	1.667
176	21.500	0.000	2.667	23.000	0.000	3.667	23.080	0.000	3.667	21.580	0.000	2.667

WING PANELING

(CAMBER SURFACE)

VORTEX PANEL CORNER POINT COORDINATES

PANEL	X_1	Y_1	Z_1	X_2	Y_2	Z_2	X_3	Y_3	Z_3	X_4	Y_4	Z_4
1	12.000	1.667	0.000	13.430	3.500	0.000	13.462	3.500	0.000	12.050	1.667	0.000
2	12.050	1.667	0.000	13.462	3.500	0.000	13.558	3.500	0.000	12.200	1.667	0.000
3	12.200	1.667	0.000	13.558	3.500	0.000	13.687	3.500	0.000	12.400	1.667	0.000
4	12.400	1.667	0.000	13.687	3.500	0.000	14.201	3.500	0.000	13.200	1.667	0.000
5	13.200	1.667	0.000	14.201	3.500	0.000	14.715	3.500	0.000	14.000	1.667	0.000
6	14.000	1.667	0.000	14.715	3.500	0.000	15.229	3.500	0.000	14.800	1.667	0.000
7	14.800	1.667	0.000	15.229	3.500	0.000	15.743	3.500	0.000	15.600	1.667	0.000
8	15.600	1.667	0.000	15.743	3.500	0.000	16.000	3.500	0.000	16.000	1.667	0.000
9	16.000	1.667	0.000	16.000	3.500	0.000	100.000	3.500	0.000	100.000	1.667	0.000
10	12.000	-1.667	0.000	12.050	-1.667	0.000	13.462	-3.500	0.000	13.430	-3.500	0.000
11	12.050	-1.667	0.000	12.200	-1.667	0.000	13.558	-3.500	0.000	13.462	-3.500	0.000
12	12.200	-1.667	0.000	12.400	-1.667	0.000	13.687	-3.500	0.000	13.558	-3.500	0.000
13	12.400	-1.667	0.000	13.200	-1.667	0.000	14.201	-3.500	0.000	13.687	-3.500	0.000
14	13.200	-1.667	0.000	14.000	-1.667	0.000	14.715	-3.500	0.000	14.201	-3.500	0.000
15	14.000	-1.667	0.000	14.800	-1.667	0.000	15.229	-3.500	0.000	14.715	-3.500	0.000
16	14.800	-1.667	0.000	15.600	-1.667	0.000	15.743	-3.500	0.000	15.229	-3.500	0.000
17	15.600	-1.667	0.000	16.000	-1.667	0.000	16.000	-3.500	0.000	15.743	-3.500	0.000
18	16.000	-1.667	0.000	100.000	-1.667	0.000	100.000	-3.500	0.000	16.000	-3.500	0.000
19	13.430	3.500	0.000	15.000	5.500	0.000	15.012	5.500	0.000	13.462	3.500	0.000
20	13.462	3.500	0.000	15.012	5.500	0.000	15.050	5.500	0.000	13.558	3.500	0.000
21	13.558	3.500	0.000	15.050	5.500	0.000	15.100	5.500	0.000	13.687	3.500	0.000
22	13.687	3.500	0.000	15.100	5.500	0.000	15.300	5.500	0.000	14.201	3.500	0.000
23	14.201	3.500	0.000	15.300	5.500	0.000	15.500	5.500	0.000	14.715	3.500	0.000
24	14.715	3.500	0.000	15.500	5.500	0.000	15.700	5.500	0.000	15.229	3.500	0.000
25	15.229	3.500	0.000	15.700	5.500	0.000	15.900	5.500	0.000	15.743	3.500	0.000
26	15.743	3.500	0.000	15.900	5.500	0.000	16.000	5.500	0.000	16.000	3.500	0.000
27	16.000	3.500	0.000	16.000	5.500	0.000	100.000	5.500	0.000	100.000	3.500	0.000
28	13.430	-3.500	0.000	13.462	-3.500	0.000	15.012	-5.500	0.000	15.000	-5.500	0.000
29	13.462	-3.500	0.000	13.558	-3.500	0.000	15.050	-5.500	0.000	15.012	-5.500	0.000
30	13.558	-3.500	0.000	13.687	-3.500	0.000	15.100	-5.500	0.000	15.050	-5.500	0.000
31	13.687	-3.500	0.000	14.201	-3.500	0.000	15.300	-5.500	0.000	15.100	-5.500	0.000
32	14.201	-3.500	0.000	14.715	-3.500	0.000	15.500	-5.500	0.000	15.300	-5.500	0.000
33	14.715	-3.500	0.000	15.229	-3.500	0.000	15.700	-5.500	0.000	15.500	-5.500	0.000
34	15.229	-3.500	0.000	15.743	-3.500	0.000	15.900	-5.500	0.000	15.700	-5.500	0.000
35	15.743	-3.500	0.000	16.000	-3.500	0.000	16.000	-5.500	0.000	15.900	-5.500	0.000
36	16.000	-3.500	0.000	100.000	-3.500	0.000	100.000	-5.500	0.000	16.000	-5.500	0.000

BODY PANELING

(CAMPER SURFACE)

VORTEX PANEL CORNER POINT COORDINATES

PANEL	X_1	Y_1	Z_1	X_2	Y_2	Z_2	X_3	Y_3	Z_3	X_4	Y_4	Z_4
37	12.000	0.000	0.000	12.000	1.667	0.000	12.050	1.667	0.000	12.050	0.000	0.000
38	12.050	0.000	0.000	12.050	1.667	0.000	12.200	1.667	0.000	12.200	0.000	0.000
39	12.200	0.000	0.000	12.200	1.667	0.000	12.400	1.667	0.000	12.400	0.000	0.000
40	12.400	0.000	0.000	12.400	1.667	0.000	13.200	1.667	0.000	13.200	0.000	0.000
41	13.200	0.000	0.000	13.200	1.667	0.000	14.000	1.667	0.000	14.000	0.000	0.000
42	14.000	0.000	0.000	14.000	1.667	0.000	14.800	1.667	0.000	14.800	0.000	0.000
43	14.800	0.000	0.000	14.800	1.667	0.000	15.600	1.667	0.000	15.600	0.000	0.000
44	15.600	0.000	0.000	15.600	1.667	0.000	16.000	1.667	0.000	16.000	0.000	0.000
45	16.000	0.000	0.000	16.000	1.667	0.000	112.000	1.667	0.000	112.000	0.000	0.000
46	12.000	-1.667	0.000	12.000	-0.000	0.000	12.050	-0.000	0.000	12.050	-1.667	0.000
47	12.050	-1.667	0.000	12.050	-0.000	0.000	12.200	-0.000	0.000	12.200	-1.667	0.000
48	12.200	-1.667	0.000	12.200	-0.000	0.000	12.400	-0.000	0.000	12.400	-1.667	0.000
49	12.400	-1.667	0.000	12.400	-0.000	0.000	13.200	-0.000	0.000	13.200	-1.667	0.000
50	13.200	-1.667	0.000	13.200	-0.000	0.000	14.000	-0.000	0.000	14.000	-1.667	0.000
51	14.000	-1.667	0.000	14.000	-0.000	0.000	14.800	-0.000	0.000	14.800	-1.667	0.000
52	14.800	-1.667	0.000	14.800	-0.000	0.000	15.600	-0.000	0.000	15.600	-1.667	0.000
53	15.600	-1.667	0.000	15.600	-0.000	0.000	16.000	-0.000	0.000	16.000	-1.667	0.000
54	16.000	-1.667	0.000	16.000	-0.000	0.000	112.000	-0.000	0.000	112.000	-1.667	0.000
55	16.000	0.000	1.667	17.500	0.000	2.667	17.550	0.000	2.667	16.050	0.000	1.667
56	16.050	0.000	1.667	17.550	0.000	2.667	17.700	0.000	2.667	16.200	0.000	1.667
57	16.200	0.000	1.667	17.700	0.000	2.667	17.900	0.000	2.667	16.400	0.000	1.667
58	16.400	0.000	1.667	17.900	0.000	2.667	18.700	0.000	2.667	17.200	0.000	1.667
59	17.200	0.000	1.667	18.700	0.000	2.667	19.500	0.000	2.667	18.000	0.000	1.667
60	18.000	0.000	1.667	19.500	0.000	2.667	20.300	0.000	2.667	18.800	0.000	1.667
61	18.800	0.000	1.667	20.300	0.000	2.667	21.100	0.000	2.667	19.600	0.000	1.667
62	19.600	0.000	1.667	21.100	0.000	2.667	21.500	0.000	2.667	20.000	0.000	1.667
63	20.000	0.000	1.667	21.500	0.000	2.667	117.500	0.000	2.667	116.000	0.000	1.667
64	17.500	0.000	2.667	19.000	0.000	3.667	19.050	0.000	3.667	17.550	0.000	2.667
65	17.550	0.000	2.667	19.050	0.000	3.667	19.200	0.000	3.667	17.700	0.000	2.667
66	17.700	0.000	2.667	19.200	0.000	3.667	19.400	0.000	3.667	17.900	0.000	2.667
67	17.900	0.000	2.667	19.400	0.000	3.667	20.200	0.000	3.667	18.700	0.000	2.667
68	18.700	0.000	2.667	20.200	0.000	3.667	21.000	0.000	3.667	19.500	0.000	2.667
69	19.500	0.000	2.667	21.000	0.000	3.667	21.800	0.000	3.667	20.300	0.000	2.667
70	20.300	0.000	2.667	21.800	0.000	3.667	22.600	0.000	3.667	21.100	0.000	2.667
71	21.100	0.000	2.667	22.600	0.000	3.667	23.000	0.000	3.667	21.500	0.000	2.667
72	21.500	0.000	2.667	23.000	0.000	3.667	119.000	0.000	3.667	117.500	0.000	2.667

NUMBER OF POINTS 672, NUMBER OF PANELS 168

I	X(I)	Y(I)	Z(I)	I	X(I)	Y(I)	Z(I)	I	X(I)	Y(I)	Z(I)	I	X(I)	Y(I)	Z(I)
1	0.0000	0.0000	0.0000	2	0.0000	0.0000	0.0000	3	1.5000	.2872	.2872	4	1.5000	0.0000	.4062
5	0.0000	0.0000	0.0000	6	0.0000	0.0000	0.0000	7	1.5000	.4062	.0000	8	1.5000	.2872	.2872
9	0.0000	0.0000	0.0000	10	0.0000	0.0000	0.0000	11	1.5000	.2872	-.2872	12	1.5000	.4062	.0000
13	0.0000	0.0000	0.0000	14	0.0000	0.0000	0.0000	15	1.5000	.0000	-.4062	16	1.5000	.2872	-.2872
17	0.0000	-0.0000	0.0000	18	0.0000	-0.0000	0.0000	19	1.5000	-.2872	-.2872	20	1.5000	-.0000	-.4062
21	0.0000	-0.0000	0.0000	22	0.0000	-0.0000	0.0000	23	1.5000	-.4062	.0000	24	1.5000	-.2872	-.2872
25	0.0000	-0.0000	0.0000	26	0.0000	-0.0000	0.0000	27	1.5000	-.2872	.2872	28	1.5000	-.4062	.0000
29	0.0000	-0.0000	0.0000	30	0.0000	-0.0000	0.0000	31	1.5000	-0.0000	.4062	32	1.5000	-.2872	.2872
33	1.5000	0.0000	.4062	34	1.5000	.2872	.2872	35	4.5000	.7388	.7388	36	4.5000	0.0000	1.0449
37	1.5000	.2872	.2872	38	1.5000	.4062	.0000	39	4.5000	1.0449	.0000	40	4.5000	.7388	.7388
41	1.5000	.4062	.0000	42	1.5000	.2872	-.2872	43	4.5000	.7388	-.7388	44	4.5000	1.0449	.0000
45	1.5000	.2872	-.2872	46	1.5000	.0000	-.4062	47	4.5000	.0000	-1.0449	48	4.5000	.7388	-.7388
49	1.5000	-.0000	-.4062	50	1.5000	-.2872	-.2872	51	4.5000	-.7388	-.7388	52	4.5000	-.0000	-1.0449
53	1.5000	-.2872	-.2872	54	1.5000	-.4062	.0000	55	4.5000	-1.0449	.0000	56	4.5000	-.7388	-.7388
57	1.5000	-.4062	.0000	58	1.5000	-.2872	.2872	59	4.5000	-.7388	.7388	60	4.5000	-1.0449	.0000
61	1.5000	-.2872	.2872	62	1.5000	-0.0000	.4062	63	4.5000	-0.0000	1.0449	64	4.5000	-.7388	.7388
65	4.5000	0.0000	1.0449	66	4.5000	.7388	.7388	67	7.5000	1.0305	1.0305	68	7.5000	0.0000	1.4573
69	4.5000	.7388	.7388	70	4.5000	1.0449	.0000	71	7.5000	1.4573	.0000	72	7.5000	1.0305	1.0305
73	4.5000	1.0449	.0000	74	4.5000	.7388	-.7388	75	7.5000	1.0305	-1.0305	76	7.5000	1.4573	.0000
77	4.5000	.7388	-.7388	78	4.5000	.0000	-1.0449	79	7.5000	.0000	-1.4573	80	7.5000	1.0305	-1.0305
81	4.5000	-.0000	-1.0449	82	4.5000	-.7388	-.7388	83	7.5000	-1.0305	-1.0305	84	7.5000	-.0000	-1.4573
85	4.5000	-.7388	-.7388	86	4.5000	-1.0449	.0000	87	7.5000	-1.4573	.0000	88	7.5000	-1.0305	-1.0305
89	4.5000	-1.0449	.0000	90	4.5000	-.7388	.7388	91	7.5000	-1.0305	1.0305	92	7.5000	-1.4573	.0000
93	4.5000	-.7388	.7388	94	4.5000	-0.0000	1.0449	95	7.5000	-0.0000	1.4573	96	7.5000	-1.0305	1.0305
97	7.5000	0.0000	1.4573	98	7.5000	1.0305	1.0305	99	10.5000	1.1669	1.1669	100	10.5000	0.0000	1.6503
101	7.5000	1.0305	1.0305	102	7.5000	1.4573	.0000	103	10.5000	1.6503	.0000	104	10.5000	1.1669	1.1669
105	7.5000	1.4573	.0000	106	7.5000	1.0305	-1.0305	107	10.5000	1.1669	-1.1669	108	10.5000	1.6503	.0000
109	7.5000	1.0305	-1.0305	110	7.5000	.0000	-1.4573	111	10.5000	.0000	-1.6503	112	10.5000	1.1669	-1.1669
113	7.5000	-.0000	-1.4573	114	7.5000	-1.0305	-1.0305	115	10.5000	-1.1669	-1.1669	116	10.5000	-.0000	-1.6503
117	7.5000	-1.0305	-1.0305	118	7.5000	-1.4573	.0000	119	10.5000	-1.6503	.0000	120	10.5000	-1.1669	-1.1669
121	7.5000	-1.4573	.0000	122	7.5000	-1.0305	1.0305	123	10.5000	-1.1669	1.1669	124	10.5000	-1.6503	.0000
125	7.5000	-1.0305	1.0305	126	7.5000	-0.0000	1.4573	127	10.5000	-0.0000	1.6503	128	10.5000	-1.1669	1.1669
129	10.5000	0.0000	1.6503	130	10.5000	1.1669	1.1669	131	12.0000	1.1785	1.1785	132	12.0000	0.0000	1.6667
133	10.5000	1.1669	1.1669	134	10.5000	1.6503	.0000	135	12.0000	1.6667	.0000	136	12.0000	1.1785	1.1785
137	10.5000	1.6503	.0000	138	10.5000	1.1669	-1.1669	139	12.0000	1.1785	-1.1785	140	12.0000	1.6667	.0000
141	10.5000	1.1669	-1.1669	142	10.5000	.0000	-1.6503	143	12.0000	.0000	-1.6667	144	12.0000	1.1785	-1.1785
145	10.5000	-.0000	-1.6503	146	10.5000	-1.1669	-1.1669	147	12.0000	-1.1785	-1.1785	148	12.0000	-.0000	-1.6667
149	10.5000	-1.1669	-1.1669	150	10.5000	-1.6503	.0000	151	12.0000	-1.6667	.0000	152	12.0000	-1.1785	-1.1785
153	10.5000	-1.6503	.0000	154	10.5000	-1.1669	1.1669	155	12.0000	-1.1785	1.1785	156	12.0000	-1.6667	.0000
157	10.5000	-1.1669	1.1669	158	10.5000	-0.0000	1.6503	159	12.0000	-0.0000	1.6667	160	12.0000	-1.1785	1.1785
161	12.0000	0.0000	1.6667	162	12.0000	1.1785	1.1785	163	14.0000	1.1785	1.1785	164	14.0000	0.0000	1.6667
165	12.0000	1.1785	1.1785	166	12.0000	1.6667	.0000	167	14.0000	1.6667	.0000	168	14.0000	1.1785	1.1785
169	12.0000	1.6667	.0000	170	12.0000	1.1785	-1.1785	171	14.0000	1.1785	-1.1785	172	14.0000	1.6667	.0000
173	12.0000	1.1785	-1.1785	174	12.0000	.0000	-1.6667	175	14.0000	.0000	-1.6667	176	14.0000	1.1785	-1.1785
177	12.0000	-.0000	-1.6667	178	12.0000	-1.1785	-1.1785	179	14.0000	-1.1785	-1.1785	180	14.0000	-.0000	-1.6667
181	12.0000	-1.1785	-1.1785	182	12.0000	-1.6667	.0000	183	14.0000	-1.6667	.0000	184	14.0000	-1.1785	-1.1785
185	12.0000	-1.6667	.0000	186	12.0000	-1.1785	1.1785	187	14.0000	-1.1785	1.1785	188	14.0000	-1.6667	.0000
189	12.0000	-1.1785	1.1785	190	12.0000	-0.0000	1.6667	191	14.0000	-0.0000	1.6667	192	14.0000	-1.1785	1.1785
193	14.0000	0.0000	1.6667	194	14.0000	1.1785	1.1785	195	16.0000	1.1785	1.1785	196	16.0000	0.0000	1.6667
197	14.0000	1.1785	1.1785	198	14.0000	1.6667	.0000	199	16.0000	1.6667	.0000	200	16.0000	1.1785	1.1785
201	14.0000	1.6667	.0000	202	14.0000	1.1785	-1.1785	203	16.0000	1.1785	-1.1785	204	16.0000	1.6667	.0000
205	14.0000	1.1785	-1.1785	206	14.0000	.0000	-1.6667	207	16.0000	.0000	-1.6667	208	16.0000	1.1785	-1.1785

209	14.0000	-.0000	-1.6667	210	14.0000	-1.1785	-1.1785	211	16.0000	-1.1785	-1.1785	212	16.0000	-.0000	-1.6667
213	14.0000	-1.1785	-1.1785	214	14.0000	-1.6667	.0000	215	16.0000	-1.6667	.0000	216	16.0000	-1.1785	-1.1785
217	14.0000	-1.6667	.0000	218	14.0000	-1.1785	1.1785	219	16.0000	-1.1785	1.1785	220	16.0000	-1.6667	.0000
221	14.0000	-1.1785	1.1785	222	14.0000	-0.0000	1.6667	223	16.0000	-0.0000	1.6667	224	16.0000	-1.1785	1.1785
225	16.0000	0.0000	1.6667	226	16.0000	1.1785	1.1785	227	20.0000	1.1785	1.1785	228	20.0000	0.0000	1.6667
229	16.0000	1.1785	1.1785	230	16.0000	1.6667	.0000	231	20.0000	1.6667	.0000	232	20.0000	1.1785	1.1785
233	16.0000	1.6667	.0000	234	16.0000	1.1785	-1.1785	235	20.0000	1.1785	-1.1785	236	20.0000	1.6667	.0000
237	16.0000	1.1785	-1.1785	238	16.0000	.0000	-1.6667	239	20.0000	.0000	-1.6667	240	20.0000	1.1785	-1.1785
241	16.0000	-.0000	-1.6667	242	16.0000	-1.1785	-1.1785	243	20.0000	-1.1785	-1.1785	244	20.0000	-.0000	-1.6667
245	16.0000	-1.1785	-1.1785	246	16.0000	-1.6667	.0000	247	20.0000	-1.6667	.0000	248	20.0000	-1.1785	-1.1785
249	16.0000	-1.6667	.0000	250	16.0000	-1.1785	1.1785	251	20.0000	-1.1785	1.1785	252	20.0000	-1.6667	.0000
253	16.0000	-1.1785	1.1785	254	16.0000	-0.0000	1.6667	255	20.0000	-0.0000	1.6667	256	20.0000	-1.1785	1.1785
257	20.0000	0.0000	1.6667	258	20.0000	1.1785	1.1785	259	20.0000	0.0000	0.0000	260	20.0000	0.0000	0.0000
261	20.0000	1.1785	1.1785	262	20.0000	1.6667	.0000	263	20.0000	0.0000	0.0000	264	20.0000	0.0000	0.0000
265	20.0000	1.6667	.0000	266	20.0000	1.1785	-1.1785	267	20.0000	0.0000	0.0000	268	20.0000	0.0000	0.0000
269	20.0000	1.1785	-1.1785	270	20.0000	.0000	-1.6667	271	20.0000	0.0000	0.0000	272	20.0000	0.0000	0.0000
273	20.0000	-.0000	-1.6667	274	20.0000	-1.1785	-1.1785	275	20.0000	-0.0000	0.0000	276	20.0000	-0.0000	0.0000
277	20.0000	-1.1785	-1.1785	278	20.0000	-1.6667	.0000	279	20.0000	-0.0000	0.0000	280	20.0000	-0.0000	0.0000
281	20.0000	-1.6667	.0000	282	20.0000	-1.1785	1.1785	283	20.0000	-0.0000	0.0000	284	20.0000	-0.0000	0.0000
285	20.0000	-1.1785	1.1785	286	20.0000	-0.0000	1.6667	287	20.0000	-0.0000	0.0000	288	20.0000	-0.0000	0.0000
289	16.0000	1.6670	0.0000	290	16.0000	3.5000	0.0000	291	15.7430	3.5000	-.0244	292	15.6000	1.6670	-.0380
293	15.6000	1.6670	-.0380	294	15.7430	3.5000	-.0244	295	15.2290	3.5000	-.1057	296	14.8000	1.6670	-.1645
297	14.8000	1.6670	-.1645	298	15.2290	3.5000	-.1057	299	14.7150	3.5000	-.1750	300	14.0000	1.6670	-.2724
301	[illegible]	1.6670	-.2724	302	14.7150	3.5000	-.1750	303	14.2010	3.5000	-.1881	304	13.2000	1.6670	-.2928
305	13.2000	1.6670	-.2924	306	14.2010	3.5000	-.1881	307	13.6870	3.5000	-.1244	308	12.4000	1.6670	-.1937
309	12.4000	1.6670	-.1937	310	13.6870	3.5000	-.1244	311	13.5585	3.5000	-.0901	312	12.2000	1.6670	-.1402
313	12.2000	1.6670	-.1402	314	13.5585	3.5000	-.0901	315	13.4621	3.5000	-.0473	316	12.0500	1.6670	-.0737
317	12.0500	1.6670	-.0737	318	13.4621	3.5000	-.0473	319	13.4300	3.5000	0.0000	320	12.0000	1.6670	0.0000
321	12.0000	1.6670	0.0000	322	13.4300	3.5000	0.0000	323	13.4621	3.5000	.0473	324	12.0500	1.6670	.0737
325	12.0500	1.6670	.0737	326	13.4621	3.5000	.0473	327	13.5585	3.5000	.0901	328	12.2000	1.6670	.1402
329	12.2000	1.6670	.1402	330	13.5585	3.5000	.0901	331	13.6870	3.5000	.1244	332	12.4000	1.6670	.1937
333	12.4000	1.6670	.1937	334	13.6870	3.5000	.1244	335	14.2010	3.5000	.1881	336	13.2000	1.6670	.2928
337	13.2000	1.6670	.2924	338	14.2010	3.5000	.1881	339	14.7150	3.5000	.1750	340	14.0000	1.6670	.2724
341	14.0000	1.6670	.2724	342	14.7150	3.5000	.1750	343	15.2290	3.5000	.1057	344	14.8000	1.6670	.1645
345	14.8000	1.6670	.1645	346	15.2290	3.5000	.1057	347	15.7430	3.5000	.0244	348	15.6000	1.6670	.0380
349	15.6000	1.6670	.0380	350	15.7430	3.5000	.0244	351	16.0000	3.5000	0.0000	352	16.0000	1.6670	0.0000
353	15.6000	-1.6670	.0380	354	16.0000	-1.6670	0.0000	355	16.0000	-3.5000	0.0000	356	15.7430	-3.5000	.0244
357	14.8000	-1.6670	.1645	358	15.6000	-1.6670	.0380	359	15.7430	-3.5000	.0244	360	15.2290	-3.5000	.1057
361	14.0000	-1.6670	.2724	362	14.8000	-1.6670	.1645	363	15.2290	-3.5000	.1057	364	14.7150	-3.5000	.1750
365	13.2000	-1.6670	.2925	366	14.0000	-1.6670	.2724	367	14.7150	-3.5000	.1750	368	14.2010	-3.5000	.1881
369	12.4000	-1.6670	.1937	370	13.2000	-1.6670	.2928	371	14.2010	-3.5000	.1881	372	13.6870	-3.5000	.1244
373	12.2000	-1.6670	.1402	374	12.4000	-1.6670	.1937	375	13.6870	-3.5000	.1244	376	13.5585	-3.5000	.0901
377	12.0500	-1.6670	.0737	378	12.2000	-1.6670	.1402	379	13.5585	-3.5000	.0901	380	13.4621	-3.5000	.0473
381	12.0000	-1.6670	0.0000	382	12.0500	-1.6670	.0737	383	13.4621	-3.5000	.0473	384	13.4300	-3.5000	0.0000
385	12.0500	-1.6670	-.0737	386	12.0000	-1.6670	0.0000	387	13.4300	-3.5000	0.0000	388	13.4621	-3.5000	-.0473
389	12.2000	-1.6670	-.1402	390	12.0500	-1.6670	-.0737	391	13.4621	-3.5000	-.0473	392	13.5585	-3.5000	-.0901
393	12.4000	-1.6670	-.1937	394	12.2000	-1.6670	-.1402	395	13.5585	-3.5000	-.0901	396	13.6870	-3.5000	-.1244
397	13.2000	-1.6670	-.2924	398	12.4000	-1.6670	-.1937	399	13.6870	-3.5000	-.1244	400	14.2010	-3.5000	-.1881
401	14.0000	-1.6670	-.2724	402	13.2000	-1.6670	-.2928	403	14.2010	-3.5000	-.1881	404	14.7150	-3.5000	-.1750
405	14.8000	-1.6670	-.1645	406	14.0000	-1.6670	-.2724	407	14.7150	-3.5000	-.1750	408	15.2290	-3.5000	-.1057
409	15.6000	-1.6670	-.0380	410	14.8000	-1.6670	-.1645	411	15.2290	-3.5000	-.1057	412	15.7430	-3.5000	-.0244
413	16.0000	-1.6670	0.0000	414	15.6000	-1.6670	-.0380	415	15.7430	-3.5000	-.0244	416	16.0000	-3.5000	0.0000
417	16.0000	3.5000	0.0000	418	16.0000	5.5000	0.0000	419	15.9000	5.5000	-.0095	420	15.7430	3.5000	-.0244
421	15.7430	3.5000	-.0244	422	15.9000	5.5000	-.0095	423	15.7000	5.5000	-.0411	424	15.2290	3.5000	-.1057
425	15.2290	3.5000	-.1057	426	15.7000	5.5000	-.0411	427	15.5000	5.5000	-.0681	428	14.7150	3.5000	-.1750
429	14.7150	3.5000	-.1750	430	15.5000	5.5000	-.0681	431	15.3000	5.5000	-.0732	432	14.2010	3.5000	-.1881
433	14.2010	3.5000	-.1881	434	15.3000	5.5000	-.0732	435	15.1000	5.5000	-.0484	436	13.6870	3.5000	-.1244
437	13.6870	3.5000	-.1244	438	15.1000	5.5000	-.0484	439	15.0500	5.5000	-.0350	440	13.5585	3.5000	-.0901
441	13.5585	3.5000	-.0901	442	15.0500	5.5000	-.0350	443	15.0125	5.5000	-.0184	444	13.4621	3.5000	-.0473

445	13.4621	3.5000	.0473	446	15.0125	5.5000	-.0184	447	15.0000	5.5000	0.0000	448	13.4300	3.5000	0.0000
449	13.4300	3.5000	0.0000	450	15.0000	5.5000	0.0000	451	15.0125	5.5000	.0184	452	13.4621	3.5000	.0473
453	13.4621	3.5000	.0473	454	15.0125	5.5000	.0184	455	15.0500	5.5000	.0350	456	13.5585	3.5000	.0901
457	13.5585	3.5000	.0901	458	15.0500	5.5000	.0350	459	15.1000	5.5000	.0484	460	13.6870	3.5000	.1244
461	13.6870	3.5000	.1244	462	15.1000	5.5000	.0484	463	15.3000	5.5000	.0732	464	14.2010	3.5000	.1881
465	14.2010	3.5000	.1881	466	15.3000	5.5000	.0732	467	15.5000	5.5000	.0681	468	14.7150	3.5000	.1750
469	14.7150	3.5000	.1750	470	15.5000	5.5000	.0681	471	15.7000	5.5000	.0411	472	15.2290	3.5000	.1057
473	15.2290	3.5000	.1057	474	15.7000	5.5000	.0411	475	15.9000	5.5000	.0095	476	15.7430	3.5000	.0244
477	15.7430	3.5000	.0244	478	15.9000	5.5000	.0095	479	16.0000	5.5000	0.0000	480	16.0000	3.5000	0.0000
481	15.7430	-3.5000	.0244	482	16.0000	-3.5000	0.0000	483	16.0000	-5.5000	0.0000	484	15.9000	-5.5000	.0095
485	15.2290	-3.5000	.1057	486	15.7430	-3.5000	.0244	487	15.9000	-5.5000	.0095	488	15.7000	-5.5000	.0411
489	14.7150	-3.5000	.1750	490	15.2290	-3.5000	.1057	491	15.7000	-5.5000	.0411	492	15.5000	-5.5000	.0681
493	14.2010	-3.5000	.1881	494	14.7150	-3.5000	.1750	495	15.5000	-5.5000	.0681	496	15.3000	-5.5000	.0732
497	13.6870	-3.5000	.1244	498	14.2010	-3.5000	.1881	499	15.3000	-5.5000	.0732	500	15.1000	-5.5000	.0484
501	13.5585	-3.5000	.0901	502	13.6870	-3.5000	.1244	503	15.1000	-5.5000	.0484	504	15.0500	-5.5000	.0350
505	13.4621	-3.5000	.0473	506	13.5585	-3.5000	.0901	507	15.0500	-5.5000	.0350	508	15.0125	-5.5000	.0184
509	13.4300	-3.5000	0.0000	510	13.4621	-3.5000	.0473	511	15.0125	-5.5000	.0184	512	15.0000	-5.5000	0.0000
513	13.4621	-3.5000	-.0473	514	13.4300	-3.5000	0.0000	515	15.0000	-5.5000	0.0000	516	15.0125	-5.5000	-.0184
517	13.5585	-3.5000	-.0901	518	13.4621	-3.5000	-.0473	519	15.0125	-5.5000	-.0184	520	15.0500	-5.5000	-.0350
521	13.6870	-3.5000	-.1244	522	13.5585	-3.5000	-.0901	523	15.0500	-5.5000	-.0350	524	15.1000	-5.5000	-.0484
525	14.2010	-3.5000	-.1881	526	13.6870	-3.5000	-.1244	527	15.1000	-5.5000	-.0484	528	15.3000	-5.5000	-.0732
529	14.7150	-3.5000	-.1750	530	14.2010	-3.5000	-.1881	531	15.3000	-5.5000	-.0732	532	15.5000	-5.5000	-.0681
533	15.2290	-3.5000	-.1057	534	14.7150	-3.5000	-.1750	535	15.5000	-5.5000	-.0681	536	15.7000	-5.5000	-.0411
537	15.7430	-3.5000	-.0244	538	15.2290	-3.5000	-.1057	539	15.7000	-5.5000	-.0411	540	15.9000	-5.5000	-.0095
541	16.0000	-3.5000	0.0000	542	15.7430	-3.5000	-.0244	543	15.9000	-5.5000	-.0095	544	16.0000	-5.5000	0.0000
545	20.0000	0.0000	1.6670	546	21.5000	.0000	2.6670	547	21.1000	.0380	2.6670	548	19.6000	.0380	1.6670
549	19.6000	.0380	1.6670	550	21.1000	.0380	2.6670	551	20.3000	.1645	2.6670	552	18.8000	.1645	1.6670
553	18.8000	.1645	1.6670	554	20.3000	.1645	2.6670	555	19.5000	.2724	2.6670	556	18.0000	.2724	1.6670
557	18.0000	.2724	1.6670	558	19.5000	.2724	2.6670	559	18.7000	.2928	2.6670	560	17.2000	.2928	1.6670
561	17.2000	.2928	1.6670	562	18.7000	.2928	2.6670	563	17.9000	.1937	2.6670	564	16.4000	.1937	1.6670
565	16.4000	.1937	1.6670	566	17.9000	.1937	2.6670	567	17.7000	.1402	2.6670	568	16.2000	.1402	1.6670
569	16.2000	.1402	1.6670	570	17.7000	.1402	2.6670	571	17.5500	.0737	2.6670	572	16.0500	.0737	1.6670
573	16.0500	.0737	1.6670	574	17.5500	.0737	2.6670	575	17.5000	.0000	2.6670	576	16.0000	0.0000	1.6670
577	16.0000	0.0000	1.6670	578	17.5000	.0000	2.6670	579	17.5500	-.0737	2.6670	580	16.0500	-.0737	1.6670
581	16.0500	-.0737	1.6670	582	17.5500	-.0737	2.6670	583	17.7000	-.1402	2.6670	584	16.2000	-.1402	1.6670
585	16.2000	-.1402	1.6670	586	17.7000	-.1402	2.6670	587	17.9000	-.1937	2.6670	588	16.4000	-.1937	1.6670
589	16.4000	-.1937	1.6670	590	17.9000	-.1937	2.6670	591	18.7000	-.2928	2.6670	592	17.2000	-.2928	1.6670
593	17.2000	-.2928	1.6670	594	18.7000	-.2928	2.6670	595	19.5000	-.2724	2.6670	596	18.0000	-.2724	1.6670
597	18.0000	-.2724	1.6670	598	19.5000	-.2724	2.6670	599	20.3000	-.1645	2.6670	600	18.8000	-.1645	1.6670
601	18.8000	-.1645	1.6670	602	20.3000	-.1645	2.6670	603	21.1000	-.0380	2.6670	604	19.6000	-.0380	1.6670
605	19.6000	-.0380	1.6670	606	21.1000	-.0380	2.6670	607	21.5000	.0000	2.6670	608	20.0000	0.0000	1.6670
609	21.5000	.0000	2.6670	610	23.0000	.0000	3.6670	611	22.6000	.0380	3.6670	612	21.1000	.0380	2.6670
613	21.1000	.0380	2.6670	614	22.6000	.0380	3.6670	615	21.8000	.1645	3.6670	616	20.3000	.1645	2.6670
617	20.3000	.1645	2.6670	618	21.8000	.1645	3.6670	619	21.0000	.2724	3.6670	620	19.5000	.2724	2.6670
621	19.5000	.2724	2.6670	622	21.0000	.2724	3.6670	623	20.2000	.2928	3.6670	624	18.7000	.2928	2.6670
625	18.7000	.2928	2.6670	626	20.2000	.2928	3.6670	627	19.4000	.1937	3.6670	628	17.9000	.1937	2.6670
629	17.9000	.1937	2.6670	630	19.4000	.1937	3.6670	631	19.2000	.1402	3.6670	632	17.7000	.1402	2.6670
633	17.7000	.1402	2.6670	634	19.2000	.1402	3.6670	635	19.0500	.0737	3.6670	636	17.5500	.0737	2.6670
637	17.5500	.0737	2.6670	638	19.0500	.0737	3.6670	639	19.0000	.0000	3.6670	640	17.5000	.0000	2.6670
641	17.5000	.0000	2.6670	642	19.0000	.0000	3.6670	643	19.0500	-.0737	3.6670	644	17.5500	-.0737	2.6670
645	17.5500	-.0737	2.6670	646	19.0500	-.0737	3.6670	647	19.2000	-.1402	3.6670	648	17.7000	-.1402	2.6670
649	17.7000	-.1402	2.6670	650	19.2000	-.1402	3.6670	651	19.4000	-.1937	3.6670	652	17.9000	-.1937	2.6670
653	17.9000	-.1937	2.6670	654	19.4000	-.1937	3.6670	655	20.2000	-.2928	3.6670	656	18.7000	-.2928	2.6670
657	18.7000	-.2928	2.6670	658	20.2000	-.2928	3.6670	659	21.0000	-.2724	3.6670	660	19.5000	-.2724	2.6670
661	19.5000	-.2724	2.6670	662	21.0000	-.2724	3.6670	663	21.8000	-.1645	3.6670	664	20.3000	-.1645	2.6670
665	20.3000	-.1645	2.6670	666	21.8000	-.1645	3.6670	667	22.6000	-.0380	3.6670	668	21.1000	-.0380	2.6670
669	21.1000	-.0380	2.6670	670	22.6000	-.0380	3.6670	671	23.0000	.0000	3.6670	672	21.5000	.0000	2.6670

I	L1	L2	L3	L4	I	L1	L2	L3	L4	I	L1	L2	L3	L4	I	L1	L2	L3	L4	I	L1	L2	L3	L4	I	L1	L2	L3	L4
1	1	2	3	4	2	5	6	7	8	3	9	10	11	12	4	13	14	15	16	5	17	18	19	20	6	21	22	23	24
7	25	26	27	28	8	29	30	31	32	9	33	34	35	36	10	37	38	39	40	11	41	42	43	44	12	45	46	47	48
13	49	50	51	52	14	53	54	55	56	15	57	58	59	60	16	61	62	63	64	17	65	66	67	68	18	69	70	71	72
19	73	74	75	76	20	77	78	79	80	21	81	82	83	84	22	85	86	87	88	23	89	90	91	92	24	93	94	95	96
25	97	98	99	100	26	101	102	103	104	27	105	106	107	108	28	109	110	111	112	29	113	114	115	116	30	117	118	119	120
31	121	122	123	124	32	125	126	127	128	33	129	130	131	132	34	133	134	135	136	35	137	138	139	140	36	141	142	143	144
37	145	146	147	148	38	149	150	151	152	39	153	154	155	156	40	157	158	159	160	41	161	162	163	164	42	165	166	167	168
43	169	170	171	172	44	173	174	175	176	45	177	178	179	180	46	181	182	183	184	47	185	186	187	188	48	189	190	191	192
49	193	194	195	196	50	197	198	199	200	51	201	202	203	204	52	205	206	207	208	53	209	210	211	212	54	213	214	215	216
55	217	218	219	220	56	221	222	223	224	57	225	226	227	228	58	229	230	231	232	59	233	234	235	236	60	237	238	239	240
61	241	242	243	244	62	245	246	247	248	63	249	250	251	252	64	253	254	255	256	65	257	258	259	260	66	261	262	263	264
67	265	266	267	268	68	269	270	271	272	69	273	274	275	276	70	277	278	279	280	71	281	282	283	284	72	285	286	287	288
73	289	290	291	292	74	293	294	295	296	75	297	298	299	300	76	301	302	303	304	77	305	306	307	308	78	309	310	311	312
79	313	314	315	316	80	317	318	319	320	81	321	322	323	324	82	325	326	327	328	83	329	330	331	332	84	333	334	335	336
85	337	338	339	340	86	341	342	343	344	87	345	346	347	348	88	349	350	351	352	89	353	354	355	356	90	357	358	359	360
91	361	362	363	364	92	365	366	367	368	93	369	370	371	372	94	373	374	375	376	95	377	378	379	380	96	381	382	383	384
97	385	386	387	388	98	389	390	391	392	99	393	394	395	396	100	397	398	399	400	101	401	402	403	404	102	405	406	407	408
103	409	410	411	412	104	413	414	415	416	105	417	418	419	420	106	421	422	423	424	107	425	426	427	428	108	429	430	431	432
109	433	434	435	436	110	437	438	439	440	111	441	442	443	444	112	445	446	447	448	113	449	450	451	452	114	453	454	455	456
115	457	458	459	460	116	461	462	463	464	117	465	466	467	468	118	469	470	471	472	119	473	474	475	476	120	477	478	479	480
121	481	482	483	484	122	485	486	487	488	123	489	490	491	492	124	493	494	495	496	125	497	498	499	500	126	501	502	503	504
127	505	506	507	508	128	509	510	511	512	129	513	514	515	516	130	517	518	519	520	131	521	522	523	524	132	525	526	527	528
133	529	530	531	532	134	533	534	535	536	135	537	538	539	540	136	541	542	543	544	137	545	546	547	548	138	549	550	551	552
139	553	554	555	556	140	557	558	559	560	141	561	562	563	564	142	565	566	567	568	143	569	570	571	572	144	573	574	575	576
145	577	578	579	580	146	581	582	583	584	147	585	586	587	588	148	589	590	591	592	149	593	594	595	596	150	597	598	599	600
151	601	602	603	604	152	605	606	607	608	153	609	610	611	612	154	613	614	615	616	155	617	618	619	620	156	621	622	623	624
157	625	626	627	628	158	629	630	631	632	159	633	634	635	636	160	637	638	639	640	161	641	642	643	644	162	645	646	647	648
163	649	650	651	652	164	653	654	655	656	165	657	658	659	660	166	661	662	663	664	167	665	666	667	668	168	669	670	671	672

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ENTER VIEW POINT VX,VY,VZ

-50000.000     50000.000     20000.000
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VORTEX PANEL GEOMETRY

NUMBER OF POINTS 192, NUMBER OF PANELS 80

I	X(I)	Y(I)	Z(I)	I	X(I)	Y(I)	Z(I)	I	X(I)	Y(I)	Z(I)	I	X(I)	Y(I)	Z(I)
1	12.0000	1.6670	0.0000	2	12.0500	1.6670	0.0000	3	12.2000	1.6670	0.0000	4	12.4000	1.6670	0.0000
5	13.2000	1.6670	0.0000	6	14.0000	1.6670	0.0000	7	14.8000	1.6670	0.0000	8	15.6000	1.6670	0.0000
9	16.0000	1.6670	0.0000	10	100.0000	1.6670	0.0000	11	13.4300	3.5000	0.0000	12	13.4621	3.5000	0.0000
13	13.5585	3.5000	0.0000	14	13.6870	3.5000	0.0000	15	14.2010	3.5000	0.0000	16	14.7150	3.5000	0.0000
17	15.2290	3.5000	0.0000	18	15.7430	3.5000	0.0000	19	16.0000	3.5000	0.0000	20	100.0000	3.5000	0.0000
21	16.0000	1.6670	0.0000	22	16.0000	3.5000	0.0000	23	16.0514	3.5000	0.0000	24	16.0800	1.6670	0.0000
25	13.4300	-3.5000	0.0000	26	13.4621	-3.5000	0.0000	27	13.5585	-3.5000	0.0000	28	13.6870	-3.5000	0.0000
29	14.2010	-3.5000	0.0000	30	14.7150	-3.5000	0.0000	31	15.2290	-3.5000	0.0000	32	15.7430	-3.5000	0.0000
33	16.0000	-3.5000	0.0000	34	100.0000	-3.5000	0.0000	35	12.0000	-1.6670	0.0000	36	12.0500	-1.6670	0.0000
37	12.2000	-1.6670	0.0000	38	12.4000	-1.6670	0.0000	39	13.2000	-1.6670	0.0000	40	14.0000	-1.6670	0.0000
41	14.8000	-1.6670	0.0000	42	15.6000	-1.6670	0.0000	43	16.0000	-1.6670	0.0000	44	100.0000	-1.6670	0.0000
45	16.0000	-1.5000	0.0000	46	16.0000	-1.6670	0.0000	47	16.0800	-1.6670	0.0000	48	16.0514	-3.5000	0.0000
49	13.4300	3.5000	0.0000	50	13.4621	3.5000	0.0000	51	13.5585	3.5000	0.0000	52	13.6870	3.5000	0.0000
53	14.2010	3.5000	0.0000	54	14.7150	3.5000	0.0000	55	15.2290	3.5000	0.0000	56	15.7430	3.5000	0.0000
57	16.0000	3.5000	0.0000	58	100.0000	3.5000	0.0000	59	15.0000	5.5000	0.0000	60	15.0125	5.5000	0.0000
61	15.0500	5.5000	0.0000	62	15.1000	5.5000	0.0000	63	15.3000	5.5000	0.0000	64	15.5000	5.5000	0.0000
65	15.7000	5.5000	0.0000	66	15.9000	5.5000	0.0000	67	16.0000	5.5000	0.0000	68	100.0000	5.5000	0.0000
69	16.0000	3.5000	0.0000	70	16.0000	5.5000	0.0000	71	16.0200	5.5000	0.0000	72	16.0514	3.5000	0.0000
73	15.0000	-5.5000	0.0000	74	15.0125	-5.5000	0.0000	75	15.0500	-5.5000	0.0000	76	15.1000	-5.5000	0.0000
77	15.3000	-5.5000	0.0000	78	15.5000	-5.5000	0.0000	79	15.7000	-5.5000	0.0000	80	15.9000	-5.5000	0.0000
81	16.0000	-5.5000	0.0000	82	100.0000	-5.5000	0.0000	83	13.4300	-3.5000	0.0000	84	13.4621	-3.5000	0.0000
85	13.5585	-3.5000	0.0000	86	13.6870	-3.5000	0.0000	87	14.2010	-3.5000	0.0000	88	14.7150	-3.5000	0.0000
89	15.2290	-3.5000	0.0000	90	15.7430	-3.5000	0.0000	91	16.0000	-3.5000	0.0000	92	100.0000	-3.5000	0.0000
93	16.0000	-5.5000	0.0000	94	16.0000	-3.5000	0.0000	95	16.0514	-3.5000	0.0000	96	16.0200	-5.5000	0.0000
97	12.0000	0.0000	0.0000	98	12.0500	0.0000	0.0000	99	12.2000	0.0000	0.0000	100	12.4000	0.0000	0.0000
101	13.2000	0.0000	0.0000	102	14.0000	0.0000	0.0000	103	14.8000	0.0000	0.0000	104	15.6000	0.0000	0.0000
105	16.0000	0.0000	0.0000	106	112.0000	0.0000	0.0000	107	12.0000	1.6670	0.0000	108	12.0500	1.6670	0.0000
109	12.2000	1.6670	0.0000	110	12.4000	1.6670	0.0000	111	13.2000	1.6670	0.0000	112	14.0000	1.6670	0.0000
113	14.8000	1.6670	0.0000	114	15.6000	1.6670	0.0000	115	16.0000	1.6670	0.0000	116	112.0000	1.6670	0.0000
117	112.0000	0.0000	0.0000	118	112.0000	1.6670	0.0000	119	113.0000	1.6670	0.0000	120	113.0000	0.0000	0.0000
121	12.0000	-1.6670	0.0000	122	12.0500	-1.6670	0.0000	123	12.2000	-1.6670	0.0000	124	12.4000	-1.6670	0.0000
125	13.2000	-1.6670	0.0000	126	14.0000	-1.6670	0.0000	127	14.8000	-1.6670	0.0000	128	15.6000	-1.6670	0.0000
129	16.0000	-1.6670	0.0000	130	112.0000	-1.6670	0.0000	131	12.0000	-0.0000	0.0000	132	12.0500	-0.0000	0.0000
133	12.2000	-0.0000	0.0000	134	12.4000	-0.0000	0.0000	135	13.2000	-0.0000	0.0000	136	14.0000	-0.0000	0.0000
137	14.8000	-0.0000	0.0000	138	15.6000	-0.0000	0.0000	139	16.0000	-0.0000	0.0000	140	112.0000	-0.0000	0.0000
141	112.0000	-1.6670	0.0000	142	112.0000	-0.0000	0.0000	143	113.0000	-0.0000	0.0000	144	113.0000	-1.6670	0.0000
145	16.0000	0.0000	1.6670	146	16.0500	0.0000	1.6670	147	16.2000	0.0000	1.6670	148	16.4000	0.0000	1.6670
149	17.2000	0.0000	1.6670	150	18.0000	0.0000	1.6670	151	18.8000	0.0000	1.6670	152	19.6000	0.0000	1.6670
153	20.0000	0.0000	1.6670	154	116.0000	0.0000	1.6670	155	17.5000	0.0000	2.6670	156	17.5500	0.0000	2.6670
157	17.7000	0.0000	2.6670	158	17.9000	0.0000	2.6670	159	18.7000	0.0000	2.6670	160	19.5000	0.0000	2.6670
161	20.3000	0.0000	2.6670	162	21.1000	0.0000	2.6670	163	21.5000	0.0000	2.6670	164	117.5000	0.0000	2.6670
165	20.0000	0.0000	1.6670	166	21.5000	0.0000	2.6670	167	21.5800	0.0000	2.6670	168	20.0800	0.0000	1.6670
169	17.5000	0.0000	2.6670	170	17.5500	0.0000	2.6670	171	17.7000	0.0000	2.6670	172	17.9000	0.0000	2.6670
173	18.7000	0.0000	2.6670	174	19.5000	0.0000	2.6670	175	20.3000	0.0000	2.6670	176	21.1000	0.0000	2.6670
177	21.5000	0.0000	2.6670	178	117.5000	0.0000	2.6670	179	19.0000	0.0000	3.6670	180	19.0500	0.0000	3.6670
181	19.2000	0.0000	3.6670	182	19.4000	0.0000	3.6670	183	20.2000	0.0000	3.6670	184	21.0000	0.0000	3.6670
185	21.8000	0.0000	3.6670	186	22.6000	0.0000	3.6670	187	23.0000	0.0000	3.6670	188	119.0000	0.0000	3.6670
189	21.5000	0.0000	2.6670	190	23.0000	0.0000	3.6670	191	23.0800	0.0000	3.6670	192	21.5800	0.0000	2.6670

I	L1	L2	L3	L4
1	1	11	12	2
7	7	17	18	8
13	27	37	38	28
19	33	43	44	34
25	53	63	64	54
31	73	83	84	74
37	79	89	90	80
43	99	109	110	100
49	105	115	116	106
55	125	135	136	126
61	145	155	156	146
67	151	161	162	152
73	171	181	182	172
79	177	187	188	178

I	L1	L2	L3	L4
2	2	12	13	3
8	8	18	19	9
14	28	38	39	29
20	45	46	47	48
26	54	64	65	55
32	74	84	85	75
38	80	90	91	81
44	100	110	111	101
50	117	119	119	120
56	126	136	137	127
62	146	156	157	147
68	152	162	163	153
74	172	182	183	173
80	189	190	191	192

I	L1	L2	L3	L4
3	3	13	14	4
9	9	19	20	10
15	29	39	40	30
21	49	59	60	50
27	55	65	66	56
33	75	85	86	76
39	81	91	92	82
45	101	111	112	102
51	121	131	132	122
57	127	137	138	128
63	147	157	158	148
69	153	163	164	154
75	173	183	184	174

I	L1	L2	L3	L4
4	4	14	15	5
10	21	22	23	24
16	30	40	41	31
22	50	60	61	51
28	56	66	67	57
34	76	86	87	77
40	93	94	95	96
46	102	112	113	103
52	122	132	133	123
58	128	138	139	129
64	148	158	159	149
70	165	166	167	168
76	174	184	185	175

I	L1	L2	L3	L4
5	5	15	16	6
11	25	35	36	26
17	31	41	42	32
23	51	61	62	52
29	57	67	68	58
35	77	87	88	78
41	97	107	108	98
47	103	113	114	104
53	123	133	134	124
59	129	139	140	130
65	149	159	160	150
71	169	179	180	170
77	175	185	186	176

I	L1	L2	L3	L4
6	6	16	17	7
12	26	36	37	27
18	32	42	43	33
24	52	62	63	53
30	69	70	71	72
36	78	88	89	79
42	98	108	109	99
48	104	114	115	105
54	124	134	135	125
60	141	142	143	144
66	150	160	161	151
72	170	180	181	171
78	176	186	187	177

ENTER VIEW POINT VX,VY,VZ

-50000.000 50000.000 20000.000

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W B - A E R O
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PROGRAM FOR CALCULATING PRESSURE AND VELOCITY DISTRIBUTIONS ON WING-BODY COMBINATIONS

SYM = 1
FIELD POINTS =   16
KUTTA CONDITION= -1
COMPRESSIBILITY RULE= 2

      AERODYNAMIC CALCULATIONS

TIME =  18.50200

TIME =  19.04100

TIME =  68.66000

TIME =  68.66800
```

NR	CONTROL ITERATION SOLUTION RESIDUAL
1	3.5107334
2	.8585406
3	.1752147
4	.0519574
5	.0217977
6	.0100959
7	.0048686
8	.0023527
9	.0010740

SINGULARITY STRENGTHS

SIGMA(I)

.01995	.01994	.01993	.01992	.01992	.01993	.01994	.01995	.01696	.01695
.01693	.01692	.01692	.01693	.01695	.01696	.01149	.01149	.01147	.01142
.01142	.01147	.01149	.01149	.00509	.00526	.00520	.00494	.00494	.00520
.00526	.00509	-.00088	.00069	.00055	-.00114	-.00114	.00056	.00069	-.00088
-.00153	.00301	.00306	-.00175	-.00175	.00306	.00300	-.00153	.00122	-.00355
-.00330	.00065	.00065	-.00330	-.00355	.00122	.00234	-.00060	-.00044	.00025
.00025	-.00044	-.00060	.00234	-.00170	-.00111	-.00072	-.00073	-.00073	-.00072
-.00111	-.00170	-.00644	-.01358	-.01476	-.00392	.01286	.02454	.03705	.07645
.07629	.03764	.02467	.01318	-.00384	-.01508	-.01437	-.00764	-.00764	-.01437
-.01508	-.00384	.01318	.02467	.03764	.07629	.07645	.03705	.02454	.01286
-.00392	-.01477	-.01358	-.00644	-.00665	-.01371	-.01482	-.00380	.01313	.02473
.03741	.07742	.07770	.03865	.02558	.01415	-.00309	-.01454	-.01392	-.00729
-.00729	-.01392	-.01454	-.00309	.01415	.02558	.03865	.07770	.07742	.03741
.02473	.01313	-.00380	-.01482	-.01371	-.00665	-.00630	-.01443	-.01722	-.00597
.01274	.02424	.03581	.05886	.05886	.03581	.02424	.01273	-.00597	-.01722
-.01443	-.00630	-.00662	-.01457	-.01550	-.00266	.01524	.02545	.03672	.05974
.05974	.03672	.02545	.01524	-.00266	-.01550	-.01457	-.00662	-.00059	-.00059
-.00029	-.00029	-.00000	-.00000						

TIME = 92.94700

THIS SOLUTION FOR EPS = 10** -4 WAS OBTAINED AFTER 9 ITERATIONS

VELOCITY AND PRESSURE DISTRIBUTION
MACH= 0.0000 ALPHA= 0.0000 DEG BETA= -0.0000 DEG

I	X	Y	Z	VX	VY	VZ	V	CP
1	1.00000	.09575	.23115	.88823	.08510	.20529	.91561	.16166
2	1.00000	.23115	.09575	.88825	.20538	.08491	.91563	.16162
3	1.00000	.23115	-.09575	.88828	.20527	-.08520	.91566	.16156
4	1.00000	.09575	-.23115	.88831	.08499	-.20536	.91569	.16152
5	1.00000	-.09575	-.23115	.88831	-.08499	-.20536	.91569	.16152
6	1.00000	-.23115	-.09575	.88828	-.20527	-.08520	.91566	.16156
7	1.00000	-.23115	.09575	.88825	-.20538	.08491	.91563	.16162
8	1.00000	-.09575	.23115	.88823	-.08510	.20529	.91561	.16166
9	3.22006	.27308	.65928	.95431	.07190	.17338	.97259	.05407
10	3.22006	.65928	.27308	.95433	.17349	.07164	.97262	.05402
11	3.22006	.65928	-.27308	.95438	.17333	-.07205	.97267	.05392
12	3.22006	.27308	-.65928	.95443	.07174	-.17347	.97271	.05383
13	3.22006	-.27308	-.65928	.95443	-.07174	-.17347	.97271	.05383
14	3.22006	-.65928	-.27308	.95438	-.17333	-.07205	.97267	.05392
15	3.22006	-.65928	.27308	.95433	-.17349	.07164	.97262	.05402
16	3.22006	-.27308	.65928	.95431	-.07190	.17338	.97259	.05407
17	6.08241	.44633	1.07754	1.00335	.04880	.11772	1.01141	-.02295
18	6.08241	1.07754	.44633	1.00332	.11784	.04852	1.01138	-.02290
19	6.08241	1.07754	-.44633	1.00344	.11755	-.04926	1.01150	-.02313
20	6.08241	.44633	-1.07754	1.00363	.04851	-.11788	1.01169	-.02352
21	6.08241	-.44633	-1.07754	1.00363	-.04851	-.11788	1.01169	-.02352
22	6.08241	-1.07754	-.44633	1.00344	-.11755	-.04926	1.01150	-.02313
23	6.08241	-1.07754	.44633	1.00332	-.11784	.04852	1.01138	-.02290
24	6.08241	-.44633	1.07754	1.00335	-.04880	.11772	1.01141	-.02296
25	9.03105	.55006	1.32796	1.02353	.02249	.05653	1.02534	-.05131
26	9.03105	1.32796	.55006	1.02236	.05598	.02365	1.02417	-.04892
27	9.03105	1.32796	-.55006	1.02267	.05534	-.02523	1.02448	-.04955
28	9.03105	.55006	-1.32796	1.02425	.02187	-.05684	1.02606	-.05280
29	9.03105	-.55006	-1.32796	1.02425	-.02187	-.05683	1.02606	-.05280
30	9.03105	-1.32796	-.55006	1.02267	-.05534	-.02523	1.02448	-.04956
31	9.03105	-1.32796	.55006	1.02236	-.05598	.02365	1.02417	-.04892
32	9.03105	-.55006	1.32796	1.02353	-.02249	.05653	1.02534	-.05131
33	11.25124	.58637	1.41563	1.02517	-.00279	.01236	1.02525	-.05113
34	11.25124	1.41563	.58637	1.00935	.00449	.01580	1.00948	-.01905
35	11.25124	1.41563	-.58637	1.01061	.00309	-.01922	1.01079	-.02171
36	11.25124	.58637	-1.41563	1.02737	-.00398	-.01288	1.02746	-.05567
37	11.25124	-.58637	-1.41563	1.02737	.00397	-.01288	1.02746	-.05568
38	11.25124	-1.41563	-.58637	1.01061	-.00309	-.01921	1.01080	-.02171
39	11.25124	-1.41563	.58637	1.00935	-.00449	.01580	1.00948	-.01906
40	11.25124	-.58637	1.41563	1.02517	.00278	.01236	1.02525	-.05113
41	13.00000	.58927	1.42262	1.02192	-.01055	.00437	1.02199	-.04446
42	13.00000	1.42262	.58927	1.04579	-.01745	.04214	1.04679	-.09576
43	13.00000	1.42262	-.58927	1.05066	-.01851	-.04469	1.05177	-.10623
44	13.00000	.58927	-1.42262	1.02719	-.01224	-.00507	1.02728	-.05530
45	13.00000	-.58927	-1.42262	1.02720	.01223	-.00507	1.02728	-.05531
46	13.00000	-1.42262	-.58927	1.05066	.01851	-.04468	1.05178	-.10623
47	13.00000	-1.42262	.58927	1.04579	.01745	.04213	1.04679	-.09577
48	13.00000	-.58927	1.42262	1.02192	.01054	.00437	1.02199	-.04446
49	15.00000	.58927	1.42262	1.00357	.01673	-.00693	1.00373	-.00748
50	15.00000	1.42262	.58927	1.02022	.01928	-.04656	1.02146	-.04338

VELOCITY AND PRESSURE DISTRIBUTION
MACH= 0.0000 ALPHA= 0.0000 DEG BETA= -0.0000 DEG

I	X	Y	Z	VX	VY	VZ	V	CP
51	15.00000	1.42262	-.58927	1.02566	.01676	.04045	1.02659	-.05389
52	15.00000	.58927	-1.42262	1.01846	.00949	.00393	1.01851	-.03737
53	15.00000	-.58927	-1.42262	1.01846	-.00950	.00393	1.01851	-.03737
54	15.00000	-1.42262	-.58927	1.02566	-.01676	.04047	1.02659	-.05389
55	15.00000	-1.42262	.58927	1.02022	-.01928	-.04657	1.02146	-.04338
56	15.00000	-.58927	1.42262	1.00357	-.01673	-.00693	1.00373	-.00748
57	18.00000	.58927	1.42262	1.03940	.01291	-.00535	1.03949	-.08054
58	18.00000	1.42262	.58927	1.00893	.00482	-.01164	1.00901	-.01810
59	18.00000	1.42262	-.58927	1.00349	.00080	.00192	1.00350	-.00700
60	18.00000	.58927	-1.42262	1.00492	.00240	.00099	1.00493	-.00988
61	18.00000	-.58927	-1.42262	1.00492	-.00240	.00099	1.00493	-.00988
62	18.00000	-1.42262	-.58927	1.00349	-.00080	.00193	1.00349	-.00700
63	18.00000	-1.42262	.58927	1.00893	-.00482	-.01164	1.00901	-.01810
64	18.00000	-.58927	1.42262	1.03940	-.01291	-.00535	1.03949	-.08054
65	20.00000	.39284	.94841	1.00000	-.00862	.01574	1.00016	-.00032
66	20.00000	.94841	.39285	1.00000	-.00542	.00726	1.00004	-.00008
67	20.00000	.94841	-.39284	1.00000	-.00231	.00669	1.00002	-.00005
68	20.00000	.39285	-.94841	1.00000	-.00079	.00705	1.00003	-.00005
69	20.00000	-.39285	-.94841	1.00000	.00078	.00705	1.00003	-.00005
70	20.00000	-.94841	-.39284	1.00000	.00230	.00670	1.00003	-.00005
71	20.00000	-.94841	.39285	1.00000	.00542	.00726	1.00004	-.00008
72	20.00000	-.39284	.94841	1.00000	.00863	.01574	1.00016	-.00032
73	15.83316	2.51701	-.01585	.91528	.01332	.08697	.91950	.15452
74	15.33263	2.51701	-.08447	.98930	.01016	.15636	1.00163	-.00326
75	14.66525	2.51701	-.18224	1.08403	-.01259	.14616	1.09391	-.19663
76	13.99788	2.51701	-.23573	1.15126	-.04331	.02742	1.15240	-.32802
77	13.33050	2.51701	-.20290	1.12021	-.03901	-.14361	1.13005	-.27701
78	12.91339	2.51701	-.13925	1.06734	-.01475	-.28896	1.10586	-.22293
79	12.76740	2.51701	-.08919	.95971	.06163	-.40343	1.04288	-.08760
80	12.68398	2.51701	-.03073	.55663	.36769	-.39759	.77659	.39690
81	12.68398	2.51701	.03073	.54813	.37414	.37764	.76357	.41696
82	12.76740	2.51701	.08919	.94903	.06954	.39587	1.03063	-.06220
83	12.91339	2.51701	.13925	1.05822	-.00825	.28504	1.09597	-.20115
84	13.33050	2.51701	.20290	1.11553	-.03599	.14265	1.12519	-.26606
85	13.99788	2.51701	.23573	1.14709	-.04091	-.02743	1.14813	-.31821
86	14.66525	2.51701	.18224	1.08079	-.01094	-.14574	1.09062	-.18946
87	15.33263	2.51701	.08447	.98709	.01099	-.15605	.99941	.00118
88	15.83316	2.51701	.01585	.91378	.01366	-.08681	.91800	.15728
89	15.83316	-2.51701	.01585	.91376	-.01366	-.08679	.91797	.15732
90	15.33263	-2.51701	.08447	.98708	-.01099	-.15608	.99940	.00119
91	14.66525	-2.51701	.18224	1.08079	.01095	-.14575	1.09063	-.18947
92	13.99788	-2.51701	.23573	1.14708	.04091	-.02743	1.14814	-.31822
93	13.33050	-2.51701	.20290	1.11554	.03599	.14264	1.12519	-.26606
94	12.91339	-2.51701	.13925	1.05822	.00825	.28504	1.09597	-.20115
95	12.76740	-2.51701	.08919	.94903	-.06954	.39586	1.03063	-.06220
96	12.68398	-2.51701	.03073	.54814	-.37413	.37762	.76357	.41697
97	12.68398	-2.51701	-.03073	.55665	-.36766	-.39759	.77660	.39689
98	12.76740	-2.51701	-.08919	.95973	-.06163	-.40342	1.04289	-.08762
99	12.91339	-2.51701	-.13925	1.06735	.01475	-.28895	1.10587	-.22295
100	13.33050	-2.51701	-.20290	1.12021	.03901	-.14360	1.13005	-.27702

VELOCITY AND PRESSURE DISTRIBUTION
MACH= 0.0000 ALPHA= 0.0000 DEG BETA= -0.0000 DEG

I	X	Y	Z	VX	VY	VZ	V	CP
101	13.99788	-2.51701	-.23573	1.15126	.04331	.02743	1.15241	-.32804
102	14.66525	-2.51701	-.18224	1.08403	.01260	.14618	1.09392	-.19665
103	15.33263	-2.51701	-.08447	.98924	-.01016	.15640	1.00162	-.00324
104	15.83316	-2.51701	-.01585	.91526	-.01332	.08695	.91948	.15456
105	15.90500	4.35341	-.00903	.90801	-.01284	.08626	.91219	.16791
106	15.61999	4.35341	-.04810	.98654	-.02012	.15612	.99902	.00195
107	15.23997	4.35341	-.10377	1.09251	-.04472	.14730	1.10330	-.21728
108	14.85996	4.35341	-.13423	1.17203	-.07103	.02674	1.17448	-.37941
109	14.47994	4.35341	-.11553	1.14922	-.05218	-.14888	1.16000	-.34559
110	14.24243	4.35341	-.07929	1.09694	-.01098	-.29604	1.13624	-.29104
111	14.15930	4.35341	-.05079	.98759	.07211	-.41189	1.07247	-.15019
112	14.11180	4.35341	-.01750	.57891	.38675	-.40570	.80579	.35070
113	14.11180	4.35341	.01750	.56851	.39477	.38110	.79012	.37572
114	14.15930	4.35341	.05079	.97514	.08158	.40298	1.05828	-.11995
115	14.24243	4.35341	.07929	1.08690	-.00343	.29163	1.12535	-.26641
116	14.47994	4.35341	.11553	1.14429	-.04860	.14782	1.15483	-.33362
117	14.85996	4.35341	.13423	1.16884	-.06874	-.02676	1.17116	-.37163
118	15.23997	4.35341	.10377	1.09076	-.04350	-.14707	1.10149	-.21328
119	15.61999	4.35341	.04810	.98564	-.01961	-.15598	.99809	.00381
120	15.90500	4.35341	.00903	.90720	-.01260	-.08618	.91137	.16940
121	15.90500	-4.35341	.00903	.90720	.01260	-.08618	.91137	.16941
122	15.61999	-4.35341	.04810	.98563	.01962	-.15598	.99809	.00382
123	15.23997	-4.35341	.10377	1.09076	.04350	-.14707	1.10149	-.21328
124	14.85996	-4.35341	.13423	1.16884	.06874	-.02676	1.17116	-.37163
125	14.47994	-4.35341	.11553	1.14429	.04860	.14782	1.15483	-.33362
126	14.24243	-4.35341	.07929	1.08690	.00343	.29163	1.12535	-.26641
127	14.15930	-4.35341	.05079	.97514	-.08158	.40297	1.05827	-.11994
128	14.11180	-4.35341	.01750	.56851	-.39477	.38109	.79011	.37572
129	14.11180	-4.35341	-.01750	.57891	-.38674	-.40571	.80580	.35069
130	14.15930	-4.35341	-.05079	.98760	-.07210	-.41189	1.07247	-.15020
131	14.24243	-4.35341	-.07929	1.09694	.01099	-.29604	1.13624	-.29105
132	14.47994	-4.35341	-.11553	1.14922	.05219	-.14888	1.16000	-.34560
133	14.85996	-4.35341	-.13423	1.17203	.07103	.02674	1.17449	-.37942
134	15.23997	-4.35341	-.10377	1.09251	.04473	.14730	1.10330	-.21728
135	15.61999	-4.35341	-.04810	.98654	.02013	.15612	.99902	.00195
136	15.90500	-4.35341	-.00903	.90801	.01284	.08626	.91219	.16792
137	20.55000	.01900	2.16700	.95331	-.07676	.09693	.96130	.07591
138	19.95000	.10126	2.16700	1.00390	-.14687	.05016	1.01583	-.03190
139	19.15000	.21846	2.16700	1.06316	-.14596	-.01280	1.07321	-.15178
140	18.35000	.28258	2.16700	1.10193	-.03124	-.08381	1.10556	-.22226
141	17.55000	.24322	2.16700	1.06245	.14434	-.06866	1.07440	-.15434
142	17.05000	.16692	2.16700	1.00186	.27404	-.01480	1.03876	-.07903
143	16.87500	.10692	2.16700	.91585	.33882	.10091	.98171	.03624
144	16.77500	.03684	2.16700	.72579	.23281	.37854	.85104	.27574
145	16.77500	-.03684	2.16700	.72579	-.23281	.37854	.85104	.27573
146	16.87500	-.10692	2.16700	.91585	-.33882	.10091	.98171	.03624
147	17.05000	-.16692	2.16700	1.00186	-.27404	-.01480	1.03876	-.07903
148	17.55000	-.24322	2.16700	1.06245	-.14434	-.06866	1.07440	-.15434
149	18.35000	-.28258	2.16700	1.10193	.03124	-.08381	1.10556	-.22225
150	19.15000	-.21846	2.16700	1.06316	.14596	-.01280	1.07321	-.15178

VELOCITY AND PRESSURE DISTRIBUTION
MACH= 0.0000 ALPHA= 0.0000 DEG BETA= -0.0000 DEG

I	X	Y	Z	VX	VY	VZ	V	CP
151	19.25000	-.10126	2.16700	1.00390	.14687	.05016	1.01582	-.03190
152	20.55000	-.01900	2.16700	.95331	.07675	.09693	.96130	.07591
153	22.05000	.01900	3.16700	.92745	-.07963	.05953	.93276	.12995
154	21.45000	.10126	3.16700	.96292	-.14771	.01930	.97438	.05059
155	20.65000	.21846	3.16700	1.02859	-.14516	-.03190	1.03927	-.08008
156	19.85000	.28258	3.16700	1.09951	-.03117	-.08352	1.10312	-.21687
157	19.05000	.24322	3.16700	1.09962	.14735	-.06007	1.11107	-.23448
158	18.55000	.16692	3.16700	1.04281	.27953	-.00119	1.07963	-.16560
159	18.37500	.10692	3.16700	.95610	.34449	.11921	1.02324	-.04702
160	18.27500	.03684	3.16700	.76389	.23580	.40258	.89509	.19881
161	18.27500	-.03684	3.16700	.76389	-.23580	.40258	.89509	.19881
162	18.37500	-.10692	3.16700	.95610	-.34449	.11921	1.02324	-.04702
163	18.55000	-.16692	3.16700	1.04281	-.27953	-.00119	1.07963	-.16559
164	19.05000	-.24322	3.16700	1.09962	-.14735	-.06007	1.11107	-.23448
165	19.85000	-.28258	3.16700	1.09951	.03117	-.08352	1.10312	-.21687
166	20.65000	-.21846	3.16700	1.02858	.14516	-.03190	1.03927	-.08007
167	21.45000	-.10126	3.16700	.96292	.14771	.01930	.97437	.05059
168	22.05000	-.01900	3.16700	.92745	.07963	.05953	.93276	.12995
169	16.03337	2.51701	0.00000	.88312	.01046	-.00000	.88318	.21999
170	16.03337	-2.51701	0.00000	.88312	-.01046	-.00000	.88318	.21999
171	16.01700	4.35341	0.00000	.87540	-.01363	-.00000	.87551	.23348
172	16.01700	-4.35341	0.00000	.87540	.01363	-.00000	.87551	.23348
173	20.79000	0.00000	2.16700	.93488	-.00000	.11614	.94207	.11251
174	22.2[illegible]000	0.00000	3.16700	.91541	-.00000	.07867	.91878	.15584
175	1.00000	.09575	.23115	.93995	-.00885	-.02152	.94024	.11595
176	18.00000	.58927	-1.42263	1.00492	.00240	.00099	1.00493	-.00988
177	15.90498	4.35340	.00903	.90717	-.01452	-.08618	.91137	.16940
178	15.90498	4.35340	-.00903	.90799	-.01460	.08626	.91219	.16791
179	12.00000	2.00000	.05000	.84990	.06146	.02377	.85245	.27333
180	13.00000	2.00000	.05000	1.11048	-.06930	-.00518	1.11265	-.23800
181	14.00000	2.00000	.05000	1.13828	-.00759	.00004	1.13831	-.29574
182	15.00000	2.00000	.05000	1.04675	.04073	.01590	1.04766	-.09760
183	16.00000	2.00000	.05000	.90202	.0255[illegible]	-.04600	.90355	.18359
184	17.00000	2.00000	.05000	.98939	.00798	-.00451	.98944	.02101
185	12.00000	2.00000	-.05000	.85059	.06105	-.03125	.85335	.27179
186	13.00000	2.00000	-.05000	1.11166	-.06987	.00142	1.11386	-.24068
187	14.00000	2.00000	-.05000	1.14196	-.00904	-.00816	1.14202	-.30422
188	15.00000	2.00000	-.05000	1.04885	.03998	-.00535	1.04963	-.10172
189	16.00000	2.00000	-.05000	.90294	.02514	.04174	.90425	.18233
190	17.00000	2.00000	-.05000	.98936	.00753	-.00256	.98939	.02110

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TOTAL COEFFICIENTS
------------------
MACH=  0.0000      ALPHA=  0.0000 DEG           BETA= -0.0000 DEG

REFA=         1.0000   REFL=         1.0000
X00 =        -0.0000   X25 =        -0.0000

CX   =        .0980
CY   =       -.0000
CZ   =        .2558
CMX  =        .0001
CMY  =      -6.4921
CMZ  =        .0003
CM00=       -6.4921
CM25=       -6.4921
XCP  =      25.3769
CL   =        .2558
CS   =       -.0000
CD   =        .0980

TIME =  88.13900
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```
          CONTROL
         ITERATION SOLUTION
NR       RESIDUAL

 1        16.7285977
 2         5.4373018
 3         1.3796924
 4          .6118607
 5          .1963723
 6          .1050171
 7          .0516406
 8          .0175025
 9          .0082352
10          .0032955
11          .0012010
12          .0006412
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SINGULARITY STRENGTHS

SIGMA(I)

.00677	-.01144	-.01145	.00675	.03249	.05071	.05072	.03252	.00432	-.01319
-.01321	.00428	.02904	.04656	.04658	.02908	-.00085	-.01804	-.01806	-.00091
.02340	.04064	.04068	.02348	-.00713	-.02411	-.02415	-.00725	.01698	.03439
.03447	.01714	-.01301	-.02867	-.02873	-.01321	.01097	.02983	.03004	.01129
-.01382	-.02657	-.02675	-.01396	.01051	.03277	.03248	.01079	-.01166	-.03295
-.03275	-.01161	.01288	.02625	.02597	.01408	-.02661	-.02974	-.02864	-.01143
.01192	.02777	.02856	.03122	.00584	.01175	.01100	.00404	-.00548	-.01242
-.01393	-.00918	-.00769	-.01408	-.01422	-.00317	.01241	.02258	.03392	.06919
.06980	.03487	.02363	.01355	-.00196	-.01286	-.01257	-.00609	-.00897	-.01573
-.01683	-.00560	.01240	.02496	.03928	.08046	.08138	.03905	.02575	.01292
-.00455	-.01487	-.01268	-.00499	-.00704	-.01362	-.01433	-.00383	.01163	.02178
.03315	.06794	.06817	.03344	.02213	.01195	-.00353	-.01401	-.01326	-.00664
-.00773	-.01415	-.01463	-.00255	.01591	.02825	.04269	.08487	.08454	.04052
.02693	.01423	-.00365	-.01486	-.01339	-.00605	-.09580	-.06334	-.06742	-.06056
-.04556	-.02616	-.01279	.04470	.07124	.08333	.07391	.07065	.04880	.03349
.03491	.08340	-.09086	-.05628	-.05703	-.04976	-.03886	-.02346	-.01073	.04453
.07313	.08305	.07360	.06887	.04452	.02650	.02758	.07783	.00008	-.00125
.00004	-.00062	-.01310	-.01091						

TIME = 107.17700

THIS SOLUTION FOR EPS = 10** -4 WAS OBTAINED AFTER 12 ITERATIONS

VELOCITY AND PRESSURE DISTRIBUTION
MACH= 0.0000 ALPHA= 0.0000 DEG BETA= 10.0000 DEG

I	X	Y	Z	VX	VY	VZ	V	CP
1	1.00000	.09575	.23115	.90389	.40124	.07859	.94206	.01581
2	1.00000	.23115	.09575	.94514	.27251	-.03997	.98446	.03084
3	1.00000	.23115	-.09575	.94519	.27241	.03969	.98445	.03086
4	1.00000	.09575	-.23115	.90397	.40113	-.07965	.99209	.01575
5	1.00000	-.09575	-.23115	.84565	.23373	-.32583	.93591	.12407
6	1.00000	-.23115	-.09575	.80440	-.13190	-.20749	.84113	.29249
7	1.00000	-.23115	.09575	.80437	-.13201	.20720	.84105	.29264
8	1.00000	-.09575	.23115	.84558	.23362	.32576	.93579	.12430
9	3.22006	.27308	.65928	.96251	.37134	.05109	1.03293	-.06694
10	3.22006	.65928	.27308	.99465	.23208	-.24910	1.02255	-.04560
11	3.22006	.65928	-.27308	.99470	.23193	.[illegible]870	1.02254	-.04558
12	3.22006	.27308	-.65928	.96263	.37117	-.05118	1.03298	-.06705
13	3.22006	-.27308	-.65928	.91722	.22988	-.29048	.98920	.02148
14	3.22006	-.65928	-.27308	.88507	-.10946	-.19061	.91136	.16834
15	3.22006	-.65928	.27308	.88502	-.10962	.19020	.91184	.16855
16	3.22006	-.27308	.65928	.91710	.22973	.29034	.98903	.02182
17	6.08241	.44633	1.07754	1.00365	.33880	-.00236	1.05930	-.12211
18	6.08241	1.07754	.44633	1.02560	.17019	-.07048	1.04201	-.08578
19	6.08241	1.07754	-.44633	1.02570	.16992	.06979	1.04202	-.08580
20	6.08241	.44633	-1.07754	1.00391	.33848	.00219	1.05944	-.12241
21	6.08241	-.44633	-1.07754	.97285	.24293	-.23437	1.02975	-.06038
22	6.08241	-1.07754	-.44633	.95064	-.06160	-.16682	.96718	.06457
23	6.08241	-1.07754	.44633	.95056	-.06190	.16605	.96694	.06502
24	6.08241	-.44633	1.07754	.97257	.24268	.23423	1.02939	-.05964
25	9.03105	.55006	1.32796	1.01590	.30978	-.06296	1.06394	-.13197
26	9.03105	1.32796	.55006	1.02542	.10545	-.09523	1.03571	-.07270
27	9.03105	1.32796	-.55006	1.02415	.10449	.09385	1.03576	-.07279
28	9.03105	.55006	-1.32796	1.01654	.30898	.06259	1.06430	-.13274
29	9.03105	-.55006	-1.32796	1.00084	.26591	-.17453	1.05017	-.10286
30	9.03105	-1.32796	-.55006	.98812	-.00411	-.14354	.99850	.00300
31	9.03105	-1.32796	.55006	.98775	-.00481	.14181	.99789	.00423
32	9.03105	-.55006	1.32796	1.00006	.26547	.17430	1.04928	-.10098
33	11.25124	.58637	1.41563	1.01255	.28532	-.10711	1.05742	-.11814
34	11.25124	1.41563	.58637	1.00144	.05389	-.10366	1.00823	-.01652
35	11.25124	1.41563	-.58637	1.00204	.05280	.10103	1.00851	-.01709
36	11.25124	.58637	-1.41563	1.01428	.28339	.10630	1.05848	-.12038
37	11.25124	-.58637	-1.41563	1.00925	.29122	-.13166	1.05864	-.12073
38	11.25124	-1.41563	-.58637	.98847	.04672	-.13888	.99927	.00146
39	11.25124	-1.41563	.58637	.98659	.04504	.13477	.99677	.00644
40	11.25124	-.58637	1.41563	1.00664	.29081	.13146	1.05602	-.11517
41	13.00000	.58927	1.42262	1.00801	.28149	-.11660	1.05305	-.10891
42	13.00000	1.42262	.58927	1.03180	.03310	-.07992	1.03542	-.07209
43	13.00000	1.42262	-.58927	1.03247	.03120	.07533	1.03568	-.07264
44	13.00000	.58927	-1.42262	1.01150	.27675	.11463	1.05492	-.11286
45	13.00000	-.58927	-1.42262	1.01148	.30084	-.12461	1.06280	-.12954
46	13.00000	-1.42262	-.58927	1.03694	.06766	-.16334	1.05190	-.10650
47	13.00000	-1.42262	.58927	1.02801	.06748	.16290	1.04302	-.08789
48	13.00000	-.58927	1.42262	1.00478	.30225	.12520	1.05670	-.11662
49	15.00000	.58927	1.42262	.99722	.31571	-.13077	1.05414	-.11122
50	15.00000	1.42262	.58927	1.01205	.06763	-.16327	1.02737	-.05548

VELOCITY AND PRESSURE DISTRIBUTION
MACH= 0.0000 ALPHA= 0.0000 DEG BETA= 10.0000 DEG

I	X	Y	Z	VX	VY	VZ	V	CP
51	15.00000	1.42262	-.58927	1.00955	.06483	.15651	1.02366	-.04788
52	15.00000	.58927	-1.42262	1.00212	.24635	.12275	1.05221	-.10714
53	15.00000	-.58927	-1.42262	1.00386	.27765	-.11501	1.04788	-.09804
54	15.00000	-1.42262	-.58927	1.01061	.03181	-.07680	1.01402	-.02824
55	15.00000	-1.42262	.58927	.99738	.02964	.07156	1.00038	-.00077
56	15.00000	-.58927	1.42262	.97942	.28276	.11712	1.02613	-.05293
57	18.00000	.58927	1.42262	1.03008	.27467	-.11377	1.07212	-.14945
58	18.00000	1.42262	.58927	.98045	.03711	-.08960	.98523	.02931
59	18.00000	1.42262	-.58927	.97130	.05153	.12440	.98059	.03844
60	18.00000	.58927	-1.42262	.98231	.27742	.11491	1.02716	-.05510
61	18.00000	-.58927	-1.42262	.99700	.27270	-.11295	1.03978	-.08114
62	18.00000	-1.42262	-.58927	1.00519	.04996	-.12060	1.01363	-.02744
63	18.00000	-1.42262	.58927	1.00675	.02761	.06667	1.00934	-.01876
64	18.00000	-.58927	1.42262	1.01713	.24923	.10323	1.05230	-.10733
65	20.00000	.39284	.94841	.98481	.30803	.08424	1.03524	-.07182
66	20.00000	.94841	.39285	.98481	.28443	.04630	1.02611	-.05289
67	20.00000	.94841	-.39284	.98481	.27595	-.00151	1.02274	-.04600
68	20.00000	.39285	-.94841	.98481	.24594	-.00587	1.01507	-.03037
69	20.00000	-.39285	-.94841	.98481	.24748	.01976	1.01562	-.03149
70	20.00000	-.94841	-.39284	.98481	.28049	.01470	1.02408	-.04874
71	20.00000	-.94841	.39285	.98481	.29511	-.03200	1.02857	-.05796
72	20.00000	-.39284	.94841	.98481	.32502	-.05324	1.03842	-.07832
73	15.83316	2.51701	-.01585	.90325	.10233	.08581	.91307	.16631
74	15.33263	2.51701	-.08447	.97626	.10033	.15391	.99340	.01316
75	14.66525	2.51701	-.18224	1.06744	.08083	.14399	1.08014	-.16669
76	13.99788	2.51701	-.23573	1.12778	.05467	.03107	1.12953	-.27585
77	13.33050	2.51701	-.20290	1.09461	.06035	-.12804	1.10372	-.21820
78	12.91339	2.51701	-.13925	1.04067	.08547	-.25919	1.07586	-.15748
79	12.76740	2.51701	-.08919	.94213	.15512	-.36236	1.02126	-.04297
80	12.68398	2.51701	-.03073	.57745	.43190	-.35440	.80349	.35441
81	12.68398	2.51701	.03073	.57432	.43433	.34701	.79931	.36110
82	12.76740	2.51701	.08919	.93896	.15766	.36005	1.01791	-.03614
83	12.91339	2.51701	.13925	1.03848	.08737	.25918	1.07365	-.15273
84	13.33050	2.51701	.20290	1.09356	.06159	.12775	1.10271	-.21598
85	13.99788	2.51701	.23573	1.12857	.05517	-.03111	1.13034	-.27767
86	14.66525	2.51701	.18224	1.06974	.08081	-.14430	1.08249	-.17179
87	15.33263	2.51701	.08447	.97927	.10004	-.15436	.99640	.00718
88	15.83316	2.51701	.01585	.90520	.10204	-.08599	.91496	.16281
89	15.83316	-2.51701	.01585	.89456	.07513	-.08498	.90173	.18689
90	15.33263	-2.51701	.08447	.96492	.07839	-.15300	.98012	.03937
91	14.66525	-2.51701	.18224	1.05895	.10237	-.14275	1.07342	-.15224
92	13.99788	-2.51701	.23573	1.13073	.13575	-.02291	1.13908	-.29750
93	13.33050	-2.51701	.20290	1.10361	.13247	.15320	1.12204	-.25897
94	12.91339	-2.51701	.13925	1.04579	.10361	.30323	1.09378	-.19637
95	12.76740	-2.51701	.08919	.93024	.02067	.41964	1.02072	-.04187
96	12.68398	-2.51701	.03073	.50529	-.30258	.39674	.71012	.49573
97	12.68398	-2.51701	-.03073	.51894	-.29225	-.42873	.73383	.46149
98	12.76740	-2.51701	-.08919	.94818	.03375	-.43224	1.04260	-.08701
99	12.91339	-2.51701	-.13925	1.06161	.11454	-.30994	1.11184	-.23620
100	13.33050	-2.51701	-.20290	1.11179	.13720	-.15481	1.13087	-.27886

VELOCITY AND PRESSURE DISTRIBUTION
MACH= 0.0000 ALPHA= 0.0000 DEG BETA= 10.0000 DEG

I	X	Y	Z	VX	VY	VZ	V	CP
101	13.99798	-2.51701	-.23573	1.13977	.13999	.02296	1.14856	-.31920
102	14.66525	-2.51701	-.18224	1.06769	.10564	.14392	1.08251	-.17182
103	15.33263	-2.51701	-.08447	.97223	.08031	.15415	.98764	.02456
104	15.83316	-2.51701	-.01585	.89948	.07609	.08545	.90673	.17784
105	15.90500	4.35341	-.00903	.89149	.13324	.08469	.90536	.18032
106	15.61999	4.35341	-.04810	.96766	.12693	.15241	.98777	.02430
107	15.23997	4.35341	-.10377	1.06812	.10498	.14409	1.08290	-.17266
108	14.85996	4.35341	-.13423	1.14194	.08200	.03263	1.14535	-.31182
109	14.47994	4.35341	-.11553	1.12147	.10018	-.12632	1.13300	-.28369
110	14.24243	4.35341	-.07929	1.07282	.13887	-.25555	1.11154	-.23553
111	14.15930	4.35341	-.05079	.97577	.21279	-.35628	1.06035	-.12433
112	14.11180	4.35341	-.01750	.61786	.48847	-.34542	.86004	.26033
113	14.11180	4.35341	.01750	.61747	.48879	.34448	.85957	.26114
114	14.15930	4.35341	.05079	.97563	.21299	.35614	1.06021	-.12405
115	14.24243	4.35341	.07929	1.07300	.13891	.25559	1.11173	-.23594
116	14.47994	4.35341	.11553	1.12169	.10026	.12634	1.13322	-.28419
117	14.85996	4.35341	.13423	1.14271	.08185	-.03264	1.14610	-.31355
118	15.23997	4.35341	.10377	1.06906	.10477	-.14422	1.08382	-.17466
119	15.61999	4.35341	.04810	.96846	.12675	-.15253	.98856	.02276
120	15.90500	4.35341	.00903	.89198	.13312	-.08474	.90583	.17947
121	15.90500	-4.35341	.00903	.89485	.15734	-.08501	.91265	.16707
122	15.61999	-4.35341	.04810	.97286	.16539	-.15468	.99887	.00226
123	15.23997	-4.35341	.10377	1.07932	.19045	-.14545	1.10560	-.22236
124	14.85996	-4.35341	.13423	1.15945	.21724	-.02007	1.17980	-.39192
125	14.47994	-4.35341	.11553	1.13213	.19598	.16481	1.16072	-.34728
126	14.24243	-4.35341	.07929	1.06776	.14565	.31880	1.12382	-.26297
127	14.15930	-4.35341	.05079	.94501	.05230	.43755	1.04270	-.08723
128	14.11180	-4.35341	.01750	.50226	-.28876	.40610	.70750	.49944
129	14.11180	-4.35341	-.01750	.52239	-.27326	-.45369	.74391	.44660
130	14.15930	-4.35341	-.05079	.96944	.07078	-.45500	1.07324	-.15184
131	14.24243	-4.35341	-.07929	1.08775	.16052	-.32753	1.14728	-.31625
132	14.47994	-4.35341	-.11553	1.14706	.20297	-.16692	1.17190	-.37335
133	14.85996	-4.35341	-.13423	1.16651	.22191	.02004	1.18760	-.41039
134	15.23997	-4.35341	-.10377	1.08371	.19308	.14604	1.11042	-.23302
135	15.61999	-4.35341	-.04910	.97545	.16657	.15509	1.00165	-.00331
136	15.90500	-4.35341	-.00903	.89695	.15853	.08521	.91483	.16309
137	20.55000	.01900	2.16700	.84642	-.04679	.23573	.87987	.22582
138	19.95000	.10126	2.16700	.91721	-.10796	.15627	.93667	.12264
139	19.15000	.21846	2.16700	1.00767	-.12638	.04694	1.01665	-.03358
140	18.35000	.28258	2.16700	1.10946	-.03232	-.10719	1.11509	-.24343
141	17.55000	.24322	2.16700	1.16125	.18549	-.22430	1.19717	-.43321
142	17.05000	.16692	2.16700	1.19916	.45058	-.32306	1.32112	-.74537
143	16.87500	.10692	2.16700	1.16093	.70256	-.28284	1.38613	-.92136
144	16.77500	.03684	2.16700	.87878	1.01019	.12885	1.34512	-.80934
145	16.77500	-.03684	2.16700	.55074	.55163	.61673	.99397	.01202
146	16.87500	-.10692	2.16700	.64294	.03521	.48160	.80408	.35346
147	17.05000	-.16692	2.16700	.77411	-.08918	.29391	.83281	.30642
148	17.55000	-.24322	2.16700	.93136	-.09880	.08907	.94081	.11487
149	18.35000	-.28258	2.16700	1.06092	.02921	-.05788	1.06290	-.12976
150	19.15000	-.21846	2.16700	1.08635	.16109	-.07215	1.10059	-.21130

VELOCITY AND PRESSURE DISTRIBUTION
MACH= 0.0000 ALPHA= 0.0000 DEG BETA= 10.0000 DEG

I	X	Y	Z	VX	VY	VZ	V	CP
151	19.95000	-.10126	2.16700	1.06008	.18129	-.05747	1.07700	-.15994
152	20.55000	-.01900	2.16700	1.03125	.10436	-.04482	1.03749	-.07638
153	22.05000	.01900	3.16700	.82759	-.05271	.18173	.84894	.27929
154	21.45000	.10126	3.16700	.89144	-.12347	.07376	.90296	.18465
155	20.65000	.21846	3.16700	.97611	-.13895	-.03621	.98661	.02660
156	19.85000	.28258	3.16700	1.08670	-.03349	-.15283	1.09791	-.20540
157	19.05000	.24322	3.16700	1.17476	.18808	-.22923	1.21161	-.46799
158	18.55000	.16692	3.16700	1.21826	.44659	-.30039	1.33185	-.77383
159	18.37500	.10692	3.16700	1.18184	.68978	-.24968	1.39100	-.93489
160	18.27500	.03684	3.16700	.90657	.97588	.16289	1.34192	-.80076
161	18.27500	-.03684	3.16700	.59798	.51144	.63004	1.00801	-.01609
162	18.37500	-.10692	3.16700	.70131	.01126	.48448	.85246	.27331
163	18.55000	-.16692	3.16700	.83568	-.10399	.29806	.84331	.20199
164	19.05000	-.24322	3.16700	.99106	-.10214	.11092	1.00246	-.00493
165	19.85000	-.28258	3.16700	1.07891	.02790	-.01166	1.07933	-.16496
166	20.65000	-.21846	3.16700	1.04981	.14695	-.02661	1.06038	-.12440
167	21.45000	-.10126	3.16700	1.00515	.16744	-.03574	1.01963	-.03964
168	22.05000	-.01900	3.16700	.99914	.10411	-.05449	1.00662	-.01328
169	16.03337	2.51701	0.00000	.87174	.05902	.00000	.87734	.23027
170	16.03337	-2.51701	0.00000	.86767	.07841	-.00000	.87120	.24101
171	16.01900	4.35341	0.00000	.85992	.13211	-.00000	.86991	.24326
172	16.01900	-4.35341	0.00000	.86439	.15897	.00000	.87889	.22756
173	20.79000	0.00000	2.16700	.92069	.17365	.11436	.94388	.10910
174	22.29000	0.00000	3.16700	.90151	.17365	.07747	.92134	.15113
175	1.00000	.09575	.23115	.92145	.36934	.00156	.94272	.01451
176	18.00000	.58927	-1.42263	.98231	.27742	.11491	1.02718	-.05510
177	15.90498	4.35340	.00903	.89195	.13137	-.08474	.90555	.17999
178	15.90498	4.35340	-.00903	.89146	.13138	.08469	.90506	.18087
179	12.00000	2.00000	.05000	.85175	.09574	.01537	.85726	.26511
180	13.00000	2.00000	.05000	1.08901	-.02669	-.01895	1.08950	-.18702
181	14.00000	2.00000	.05000	1.12109	.02511	-.01207	1.12151	-.25779
182	15.00000	2.00000	.05000	1.03669	.07478	-.00744	1.03941	-.08038
183	16.00000	2.00000	.05000	.89161	.06161	-.04968	.89512	.19877
184	17.00000	2.00000	.05000	.97057	.04329	-.00143	.97153	.05612
185	12.00000	2.00000	-.05000	.85201	.09555	-.01906	.85757	.26458
186	13.00000	2.00000	-.05000	1.08886	-.02645	.00497	1.08919	-.18634
187	14.00000	2.00000	-.05000	1.12063	.02846	-.00213	1.12099	-.25663
188	15.00000	2.00000	-.05000	1.03653	.07498	-.01193	1.03931	-.08017
189	16.00000	2.00000	-.05000	.89017	.06191	.05155	.89381	.20110
190	17.00000	2.00000	-.05000	.97001	.04410	.01540	.97113	.05691

```
TOTAL COEFFICIENTS
------------------
MACH=  0.0000     ALPHA=  0.0000 DEG          BETA= 14.0000 DEG

REFA=        1.0000   REFL=        1.0000
X00 =       -0.0000   X25 =       -0.0000

CX   =       -.0564
CY   =       2.9684
CZ   =        .6567
CMX  =      -1.5628
CMY  =     -14.1404
CMZ  =      21.0376
CM00=      -14.1404
CM25=      -14.1404
XCP  =      21.5337
CL   =        .6567
CS   =       2.9136
CD   =       -.5710
```

LIST OF SYMBOLS

A	Aerodynamic matrix
a	Aerodynamic influence coefficient
B	Prandtl-Glauert factor $\sqrt{1-M^2}$
C	Aerodynamic coefficient
c	Chord
D	Perpendicular distance from panel edge to control point
d	Distance between panel corner points
J	Geometrical parameter for source panel
L	Length of line vortex
M	Mach number, pitching moment
N	Number of singularities
NL	Number of vortex lattices
NS	Number of source lattices
n	Direction cosine of normal vector
P,Q	Geometrical parameters for source panels
q	Magnitude of resultant velocity vector
R	Component of free-stream velocity vector normal to panel
r	Distance from panel corner point to control point
S	Area
T	Geometrical parameter for source panel
t	Component of transformation matrix
U,V,W	Components of resultant velocity vector
u,v,w	Perturbation velocity components

List of Symbols (cont'd)

V	Velocity vector magnitude
x,y,z	Cartesian coordinates of point
α	Angle of attack
β	Angle of yaw
γ	Vortex strength
ε	Small reference value
κ	Ratio of specific heats for air
Θ	Angle between panel edge and line joining panel corner to control point
σ	Singularity strength
s	Source strength
ξ,η	Panel coordinates

Mathematical Symbols

$\rightarrow$	Vector
$\mid\ \mid$	Absolute value
$\times$	Cross product
$\bullet$	Scalar product
$-$	Average value
$\lfloor\ \rfloor$	Matrix quantity
$\{\ \}$	Vector array
Σ	Summation
$\int$	Integral
Δ	Incremental value

List of Symbols (cont'd)

Subscripts

a	Analogous body
D	Drag
i	Panel control point
j	Panel corner point
L	Lift
M	Moment
P	Pressure
s	Source
S	Side
v	Vortex
W	Wing
X	Axial
Y	Lateral
Z	Normal
x,y,z	Reference axis direction